

INVITED CONTRIBUTION

STATE OF THE ART ON SWIMMING PHYSIOLOGY AND COACHING PRACTICE: BRIDGING THE GAP BETWEEN THEORY AND PRACTICE

Kari L. Keskinen

Finnish Society for Research in Sport and Physical Education, Helsinki, Finland.

The aim of the present paper was to survey the state of the art on swimming physiology as related to coaching practice in order to help bridging the gap between theory and practice. Systematic literature searches were performed through the years 1990 – 2006 utilising EBSCOhost Research Databases and SportDiscus. Ovid Medline was used to scan materials for randomized controlled trials. The searches were done in three steps using both key words and thesaurus decodes. In the first phase, “Swimming” without limitations was fed to the system and repeated with animals excluded, second, “Swimming” and “Physiology” were used and third, some subdivisions were connected to the precedents. One may conclude that the body of knowledge for the improvement of sports coaching and fitness training in Swimming is large and well represented in the subdivisions of Swimming Physiology.

Key Words: Swimming, physiology, literature review.

INTRODUCTION

The description of the art of swimming dates back to 5000 y BC by Egyptian hieroglyphs and paintings. Kaheir papyrus 3000 y BC mentioned medical findings related to protection against Schistosomiasis while swimming. (1) The modern history of Swimming Physiology dates back to early 1900's where we recall pioneering work of e.g. Du Bois-Reymond (7) and Liljenstrand & Stenström (14) in cardiovascular and metabolic aspects of swimming as well as Hill (9) who explored the basic relationships between the maximal performance and maximal oxygen consumption describing also the role of lactic acid in the muscle after exercise. Holmér & Åstrand laid the basics for physiological testing of swimmers in 1970's (10). Since then the literature has accumulated rapidly. The aim of the present paper was to survey the state of the art on swimming physiology as related to coaching practice in order to help bridging the gap between theory and practice.

METHODS

Systematic literature searches were performed through the years 1990 – 2006 utilising EBSCOhost Research Databases and SportDiscus. Ovid Medline was used to scan materials for randomized controlled trials (RCT). The searches were done in three steps using both key words and thesaurus decodes. In the first phase, “Swimming” without limitations was fed to the system and repeated with animals excluded, second, “Swimming” and “Physiology” were used and third, some subdivisions were connected to the precedents. Table 1 presents the studied subcategories which were further scanned for content analysis.

Table 1. Scientific papers on Swimming Physiology as divided into subcategories. The frequencies have been obtained by key words and (thesaurus decodes).

Sub-categories	All papers	1990-2006	Advanced	Intermediate
Cardiovascular system	448	228 (180)	188 (146)	23 (22)
Metabolism	531	142	112	14
Training	395 (187)	179 (74)	88 (21)	26 (16)
Exercise	111 (28)	50 (11)	37 (3)	6 (4)
Coaching	62 (47)	37 (29)	1 (1)	8 (4)
Testing	147 (70)	62 (33)	37 (13)	8 (5)
Lactate		362	149	27
Aer / Anaer Thresh / Metab		189	140	23
Critical velocity / speed / power		19	19	
VO ₂ , VO ₂ max, Aer Cap, CO ₂		189	162	21
Heart Rate		120	83 (46)	13 (12)
Respiratory / ventilatory response		58	32	4
Oxygen Consumption		92	86	5
VO ₂ max		57	57	0

RESULTS

When the time line was kept unlimited a total of 22.192 hits by key words (16.362 by thesaurus decode) were observed with Swimming. When animal experiments were excluded 21.882 (16.067) hits were found. During the 1990 – 2006 there were 9.778 (7092) papers in English including 2.212 (1451) in advanced and 688 (507) in intermediate category. When Swimming and Physiology (no animals) were connected 1975 hits were found, out of which 833 (557 advanced, 110 intermediate) appeared during 1990 – 2006. When the subdivisions were added to the searches the number of papers remained at reasonably low levels to enable content analysis (table 1). RCT was found in 61 papers, none with population based sampling. Materials concerning data to be utilised by practitioners in sports coaching and fitness training were well represented in all subdivisions.

DISCUSSION

The major finding of the study was that the subdivisions of swimming physiology included approaches that may be considered valid for sports coaching and fitness training. Previously Keskinen (11) reported 539 items (peer reviewed, books chapters and books) on Swimming Physiology through the years 1893 – 1990. Clarys (1) reported that by the mid 1990's there were 685 peer reviewed papers on Swimming out of which 18 % were on Swimming Physiology. When these data connect to the present one, an expansion of scientific approaches in swimming literature may be observed. RCT has become the golden standard to obtain empirical evidence on the effectiveness of comparable treatments. In Medical and Nutritional sciences RCT has become established as the primary and in many instances, the only acceptable source of evidence for the efficacy of new treatments (16). The present data showed that in Swimming Physiology 61 papers used RCT during the years 1990 – 2006. Nearly half of the papers studied the effects of nutritional supplements, mostly creatine phosphate, on the performance. One third of the papers concentrated on making comparisons between concurrent protocols for training. The studies seemed to have adopted the commonly accepted policy in statistics that an active control group be used (3). A mere handful of papers, with competitive swimmers as the study group, concentrated on studies of

some kind of training effects or swimming conditions (e.g. wet suit) affecting the performance. All studies, however, used relatively small number of subjects so that only weak evidence on the efficacy of treatments could be obtained. It is promising that RCT has been adopted by swimming scientists as a method of choice in training studies.

There are several testing protocols available for regular testing of swimmers with lactates. Commonly most used protocol seems to be the two speed test (15) even though incremental series of e.g. 7 x 200 m have increased popularity. There are studies pointing out the differences between concurrent methods to interpret the results into practice (12).

Analyses of the thresholds to observe points of aerobic to anaerobic metabolism, has been based either on fixed blood lactate concentrations (2-4 mmol l⁻¹) or on visual inspection. A replacement has been proposed by Cheng et al (4).

Development of portable miniaturised technology, have helped both practitioners and scientists to use lactate measurements after mid 1990's. Since then several approaches have utilised quick analyses in both diagnosing individual lactate profiles to define training zones as well as to collect data for research purposes. Basic physiological approaches seldom use portable analysers but instead prefer analysing lactates by the traditional method of reference, i.e. enzymatically from samples originally stored in perchloric acid. During the latest years, however, Yellow Springs®, Accusport® and LactatePro® apparatuses have become more and more popular in the laboratories world wide and being used for lactate determination. Even though not well documented, competitive swimming teams use primarily portable technology for immediate feedback during training and competitions.

Open indirect calorimetric methods have been progressively preferred to the classical Douglas bag technique by some investigators for the measurement of expiratory gases to assess oxygen consumption and energy expenditure in athletes involved in endurance sports, mostly due to its more advantageous sampling capability and practicality. Requisite machinery to explore human aerobic energetics during field conditions have become available with the improvement of miniaturized metabolic measurement systems within an acceptable level of accuracy (Cosmed®, Metamax®, Deltatrack®, Cortex®). However, environmental factors have hindered measurements in swimming. A respiratory snorkel and valve system as described by Toussaint et al. (18) was originally developed to collect respiratory gases in Douglas bags during swimming, although the collection procedure is not easily handled in field testing conditions and require relatively long steady-state sampling if accuracy has to be guaranteed. Accordingly, this piece of equipment has been modified for BxB gas analysis to be used in connection with the K4 b² portable metabolic cart in swimming pool conditions, and biologically validated in the laboratory with human subjects (13). First findings of using BxB technology in swimming was reported by Rodríguez et al. (17) describing oxygen uptake on-kinetics responses to maximum 100-m and 400-m swims. The determination of VO₂ by post-exercise measurements (5) is still in active use. Attempts have been made to explore the slow component of the VO₂ kinetics (6) as well as an interesting new concept of time limit has been presented (2, 8) to diagnose effects of swimming training and performance. It is the time duration a swimmer can perform at lowest speed corresponding to maximal oxygen uptake. Since its validation (19), the Critical Speed concept has been a

topic or a co-topic in some 37 studies. This concept is easily available for coaches to follow the conditioning of the athletes. However, there is no information available about the popularity of the method among practitioners. The same yields for the measurement of HR which can be easily measured by swimmers themselves either manually or by HR monitors.

CONCLUSIONS

The body of knowledge for the improvement of sports coaching and fitness training in Swimming is large and well represented in the subdivisions of Swimming Physiology.

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EFFECTS OF STROKING PARAMETERS CHANGES ON TIME TO EXHAUSTION

Morgan Alberty¹, Michel Sidney¹, François Huot-marchand¹, Jeanne Dekerle^{1,2}, Philippe Gorce³, Ghislaine Lensel¹, Patrick Pelayo¹

¹Human Movement Studies Laboratory, University of Lille 2, Rochin, France

²Chelsea School, University of Brighton, Eastbourne, United Kingdom

³Performance and Sport Ergonomy Laboratory, University of Toulon-Var, La Garde, France.

The aim of this study is to assess the technical modifications under constrained swimming during time to exhaustion tests (TTE). Ten swimmers performed a maximal 400-m front crawl test (V_{400}), and 3 sets (S_1 , S_2 , S_3) of 4 TTE at 95, 100, 105, and 110% of V_{400} . In S_1 , swimmers had to sustain the velocities for the longest time as possible and the mean stroke rate (SR) was calculated (SR_{S_1}). In S_2 and S_3 , velocities and SR were imposed (at SR_{S_1} and $SR_{S_1}-5\%$, respectively). TTE of S_2 and S_3 were shorter than those of S_1 . During S_3 , an increase of the glide time was observed while propulsive time remained stable compared to S_2 . Swimming with a longer stroke length does not induce only a specific improvement of force production, but also the ability of the swimmers to adopt a more streamlined position to reduce drag.

Key Words: Front crawl, task constraint, technique.

INTRODUCTION

Reaching high velocities depends on the ability of swimmers to cover a long distance per stroke (SL) and to reproduce it with a high frequency (SR). Even if the experts have to find the best combination between their SL and SR to swim at the highest velocity (8), they have improved their SL to reach such a level (3). A high SL value is associated with a high swimming economy [4]. In fact, it reflects a high propulsive efficiency (11) and the ability of the swimmer to decrease drag (10). Based on this statement, coaches base their training program in an attempt to develop SL and improve the ability of the swimmers to maintain it. As SL is also related to force production (9), training programs include muscular reinforcement sessions to develop general strength and convert it into a specific one. This conversion can be made notably with a set in which a given velocity has to be maintained with less stroke cycles per length. An increase in SL should induce temporal and kinetics changes

of the different phases of the stroke cycle, thus modifying the propulsive and resistive impulses that govern the aquatic displacement of the swimmers (10). The literature dealing with the acute effects of SR/SL changes on technique is scarce in swimming. Indeed, how do swimmers modify the duration of the different parts of the stroke cycle while swimming with a reduced stroke rate?

Coaches impose an average SR, regularly used by the swimmer, with the aim to increase the ability to maintain SL constant despite the apparition of fatigue. This ability characterizes a high performance level (3). No data have been yet reported on TTE at given speeds while imposing a fixed SR. This could be useful for coaches to know the maximal duration while swimming under these constraints as they used to train in this way in an intermittent set.

Hence, the aim of this study was twofold: 1) to provide data about the time during which the swimmer is able to sustain selected swimming velocities with and without imposed stroke rate; 2) to evaluate the modifications of the stroke cycle regarding the duration of the different stroke phases while decreasing SR at an imposed constant speed.

METHODS

Ten well trained swimmers (20.3 ± 1.7 years; two females and eight males) volunteered for this study. Height, body mass and arm span mean values were, 180 ± 6 cm and 170 ± 7 , and 73 ± 5 kg and 62 ± 5 , and 187 ± 5 and 172 ± 7 cm respectively for males and females. They have a 12 ± 2 years of mean training experience, and trained at a frequency of 6 ± 2 training sessions per week during the study. Their performances in the 400 m front crawl stroke corresponded to a mean percentage of $76.3 \pm 3.6\%$ of the world record on the short course pool. They were informed of the procedure and gave written consent to participate.

First, swimmers performed a maximal 400-m front crawl test. The 400-m velocity (V_{400}) is usually used by coaches as a reference to set training intensities. It has been shown to correspond to the slowest velocity that elicits VO_{2max} during an incremental test lying within the severe intensity domain according to Dekerle et al. (6). Then subjects had to perform three sets of four TTE, each performed at 95, 100, 105 and 110% of V_{400} (TTE_{95} , TTE_{100} , TTE_{105} , TTE_{110}). During the first set (S_1), the velocity was imposed and swimmers had to maintain it for the longest possible time. For each TTE, a mean individual SR was calculated (SR_{S_1}). For the second and third set of TTE (S_2 and S_3), swimmers were required to sustain the same velocities until exhaustion while maintaining constant their SR at values equal to SR_{S_1} (S_2) and SR_{S_1} minored by 5% (S_3). The subjects performed all the trials with at least 24 h of rest. To avoid any influence of circadian variance, they performed their trials at the same time of the day. All the TTE were performed in a randomized order to avoid a fatigue effect on the results. The subjects were encouraged during each trial to perform as well as possible in each TTE.

The tests were performed in a 25-m indoor swimming pool. During each TTE, swimmers were continuously videotaped by two cameras placed on a trolley (one above in a plunging view and one below the water surface) and pushed by a researcher. Velocities were imposed by a visual pacer with flashing lights (Baumann) which is composed of an independant computer and a row where lights are placed every 5 m from the wall of the pool. If necessary, two operators walked on each edge of

the pool at the prescribed velocity so that the swimmers could see them. Some marks were laid out according to the lamps of the visual pacer and the corresponding split times were provided by the operators. The swimmer was asked to maintain their feet at the level of the pacer/light. When the researcher's feet or the light reached the swimmer's head, the test was stopped. The duration of each TTE from the start of the trial till the point to exhaustion was measured at the nearest second. SR was imposed by a waterproof metronom placed on the swimmer's cap (Tempo Trainer, Finis ®)

The duration of TTE in each set is measured (s) and the durations TTE of S₂ and S₃ are expressed also in percentage of the duration of TTE in S₁ of the same relative intensity. During the TTE of S₁, the period (T in s) of the cycle was measured cycle by cycle each lap with personal PC software, hence SR was calculated with the following formulae SR=60/T where SR is in cycle.min⁻¹.

Swimming velocity (V in m.s⁻¹) was measured for each lap to ensure that the correct velocity was imposed and to determine SL (m.cycle⁻¹) using the following equation:

$$SL = V/(SR/60)$$

The absolute durations (in s) of the different stroke phases [glide (A), traction (B), push (C) and recovery phases (D)], and the sum of propulsive (B+C) and non propulsive time (A+D) were measured. For the calculation of the Index of Coordination (IdC in percentage of the stroke cycle duration), according to the methodology of Chollet et al. [1].

Values are presented as Mean ± SD. The Normal Gaussian distribution of the data was verified by the Shapiro-Wilk's test. A paired student "t" test (comparison of 2 sets of data) or a one-way analysis of variance (ANOVA) were used to detect any significant difference between parameters. The threshold for significance was set at the 0.05 level of confidence.

RESULTS

Mean TTE values and the range of distances covered during each tests are summarized in Table 1.

Table 1. Mean (±SD) exhaustion times (in s) and range of distances (m) covered during each test.

	TTE ₉₅	TTE ₁₀₀	TTE ₁₀₅	TTE ₁₁₀	
Exhaustion times	S ₁ (s)	670 (117)	238 (43)	122 (27)	68 (14)
	S ₂ (s)	333 (54)*	177 (58)*	77 (25)*	47 (10)*
	S ₃ (s)	262 (80)*	111 (46)* ^Δ	60 (19)*	37 (8)* ^Δ
	S ₂ (% of S ₁)	49 (11)	74 (19)	62 (18)	69 (8)
	S ₃ (% of S ₁)	40 (12)	46 (20)	49 (16)	54 (10)
Range of Distances (m)	S ₁	1075-600	400-225	200-125	125-75
	S ₂	500-300	275-175	125-75	100-50
	S ₃	450-200	200-75	125-50	75-50

* Significant difference compared to S₁ for each speed (p<0.05)

Δ Significant difference between S₂ and S₃ for each speed (p<0.05)

For each intensity, TTE of S₂ and S₃ were significantly shorter than TTE of S₁ (p<0.05). The duration of TTE₁₀₀ and TTE₁₁₀ of S₃ were significantly shorter than TTE₁₀₀ and TTE₁₁₀ of S₂ (P<0.05).

Mean values of V, SL, and SR at the beginning and the end for each TTE of S₁ are shown in Table 2. For each intensity, V remains constant while SL decreases significantly and SR increases significantly (only significant for TTE₉₅ and TTE₁₀₀).

Table 2. Mean values (±SD) of Velocity (V), Stroke Length (SL), Stroke Rate (SR), at the beginning and the end of the different Time to Exhaustion (TTE) of the first set (S₁).

	TTE ₉₅		TTE ₁₀₀		TTE ₁₀₅		TTE ₁₁₀	
	Start	End	Start	End	Start	End	Start	End
SL (m.cycle ⁻¹)	2.49 (0.22)	2.23** (0.14)	2.46 (0.25)	2.27** (0.22)	2.41 ¹ (0.2)	2.21* (0.2)	2.40 ^{1,2} (0.19)	2.31* (0.22)
SR (cycle.min ⁻¹)	31.12 (3.73)	34.2** (2.93)	33.74 (3.54)	36.55** (2.94)	37.16 ^{1,2} (3.53)	39.30 (2.89)	39.06 ^{1,2} (3.29)	39.75 (4.1)

*,** : significant difference between the beginning and the end of the TTE at p<0.05 and p<0.01 respectively

¹ Significantly different from TTE₉₅ (p<0.05)

² Significantly different from TTE₁₀₀ (p<0.05)

³ Significantly different from TTE₁₀₅ (p<0.05).

Mean values of V, SL, SR, A+D, B+C, and the IdC, for each TTE of S₂ and S₃ are shown in Table 3. Mean duration values of phase A, B, C, and D are represented in the fig. 1. The SL increased significantly within each TTE of S₃. A+D always increases significantly. Except from TTE₁₀₅ mean duration values of phase A increased significantly (0.66 ± 0.16s to 0.71 ± 0.18s, 0.59 ± 0.14s to 0.66 ± 0.14s, 0.51 ± 0.14s to 0.57 ± 0.16s for TTE₉₅, TTE₁₀₀, and TTE₁₁₀ respectively). Mean duration values of phase D remained stable or increased significantly (0.38 ± 0.07s to 0.41 ± 0.05s and 0.34 ± 0.03s to 0.37 ± 0.04 for TTE₉₅ and TTE₁₁₀ respectively). Mean duration values of B+C increased significantly only for TTE₁₀₅. Phase C increased significantly for TTE₁₀₅ (0.36 ± 0.03s to 0.37 ± 0.03s). Except from TTE₁₀₅ of S₃, the mean IdC values decreased significantly for the studied intensities.

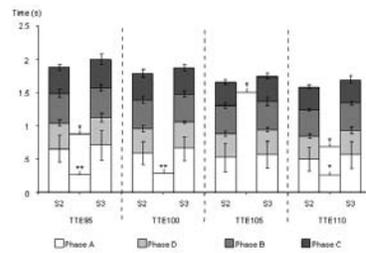


Figure 1. Representation of the mean durations of the phases A, B, C, and D during TTE of S₂ and S₃. *,** : Significant difference between S₂ and S₃ at p<0.05 and p<0.01 respectively.

Table 3 : Mean Values (\pm SD) of velocity (V), stroke length (SL), stroke rate (SR), different stroke phases (A, B, C, and D in s), Index of Coordination (IdC).

	TTE ₉₅		TTE ₁₀₀		TTE ₁₁₀			
	S ₂	S ₃	S ₂	S ₃	S ₂	S ₃	S ₂	S ₃
V	1.28	1.28	1.38	1.38	1.47	1.45	1.51	1.50
(m.s ⁻¹)	(0.1)	(0.1)	(0.1)	(0.11)	(0.13)	(0.1)	(0.11)	(0.12)
SL	2.44	2.54**	2.46	2.60***	2.43	2.52**	2.38	2.54*
(m.cycle ⁻¹)	(0.19)	(0.17)	(0.31)	(0.33)	(0.24)	(0.27)	(0.21)	(0.3)
SR	31.79	30.23***	33.93	32.25***	36.70	34.92***	38.23	35.8**
(cycle.min ⁻¹)	(3.44)	(2.54)	(3.12)	(3.17)	(4.37)	(3.98)	(3.3)	(3.43)
A+D (s)	1.03	1.13***	0.96	1.04**	0.89	0.94*	0.84	0.94*
	(0.16)	(0.18)	(0.13)	(0.13)	(0.18)	(0.17)	(0.14)	(0.16)
B+C (s)	0.88	0.87	0.82	0.82	0.76	0.80*	0.74	0.75
	(0.07)	(0.08)	(0.07)	(0.07)	(0.05)	(0.06)	(0.02)	(0.04)
IdC (%)	-3.82	-6.17*	-3.72	-5.76**	-3.37	-3.82	-2.84	-4.83*
	(2.89)	(5)	(3.85)	(3.54)	(4.52)	(4.1)	(4.54)	(4.2)

*, **, *** : significant difference between S₂ and S₃ at $p < 0.05$, $p < 0.01$, and $p < 0.001$, respectively.

DISCUSSION

The main findings of the present study are the technical modifications induced by swimming with a lowered SR at imposed velocities. Moreover, the present results provide an estimation of the range of the duration/length of the repetitions that could be proposed to the swimmers with an averaged of lowered SR.

Analyses of stroking parameters during tests performed at constant velocities surrounding the velocity at maximal lactate steady state (V_{mlss}) underlined that below it, swimmers are able to maintain their SL and SR constant over the entire duration of exercise, but above, they have to change the SL-SR combination to maintain the required velocity (6, 12). Accordingly, in the present study, in order to maintain an imposed severe speed (V₄₀₀), i.e. higher than V_{MLSS}, swimmers increase their SR and decrease their SL (see TTE of S₁). Without this SL-SR manipulation, times to exhaustion are shortened as highlighted by the shorter exhaustion times in S₂ and S₃. This decrease in TTE is dependent on the intensity imposed (7) and is greater when swimmers have to swim with lower stroke rate (S₃). The latter phenomenon could be explained via the analysis of the different phases of the stroke cycle. To satisfy the conditions of the tests in S₃, swimmers had to increase their stroke lengths inducing their stroke cycle to be reorganised. It is well accepted that SL reflect the resistive and propulsive impulses, and the propulsive efficiency (10). Hence, the examination of the modifications of the temporal structure of the stroke cycle during the TTE of S₃ could provide some information about the modification of the time of application of forces. Results showed that the swimmers always increase the non propulsive parts of their stroke cycle whereas the sum of the propulsive phases remains stable, except for TTE₁₀₅. The swimmers increase especially the glide phase (A) and concomitantly decrease their IdC. It means that the time during which resistive forces are applied, with absence of propulsion, is increased. Hence, to avoid an increase of the resistive impulse, a more streamlined position can be suggested. Thus, results of the present study show that asking the swimmers to increase their SL while keeping a given velocity, does not necessary induce an improvement in the production

of propulsive impulses.

The increase of the whole propulsive time is observed only for one intensity, whereas the duration of phase C increases in TTE₁₀₅. During this test, swimmers seem to put emphasis on their stroke phases to produce forces for longer periods. Nevertheless, propulsive time generally did not change, suggesting that the times during which the propulsive forces are applied remain constant. As stroke length increases, and velocity remains constant, it can be supposed that the magnitude of propulsive force increases too. This could be accomplished with a modification of the orientation of the propulsive surfaces and/or higher muscular forces. Each one could induce an unusual muscular sollicitation that can not be sustained during a long time, and could explain the shorter TTE of S₃ compared to those of S₁ and S₂.

The decreases in TTE of S₃ are lower with the increase in the velocity. This was not expected. Indeed, the highest the velocity, the fewest the number of SL-SR combination the swimmer is able to employ (5). Physiological phenomenon, according to the energy supply system, could play a role to explain these results (2). Finally, the mean durations of TTE of S₂ seem to follow the same logic, except from TTE₁₀₀.

CONCLUSION

This study shows that constraining swimmers to increase their stroke lengths at given velocities is not only associated with an improvement of propulsion. In fact, the duration of the glide phase mainly increase. Hence, this kind of technical work has to be carefully used in training. The ability of the swimmers to adopt a more streamlined position to reduce drag during the glide phase has to be taken into consideration.

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DIFFERENCE BETWEEN GENERAL AND SPECIFIC SWIMMING ABILITIES OF JUNIOR TOP WATER POLO PLAYERS BASED ON THEIR POSITION WITHIN THE TEAM

Zoran Bratuša¹, Milivoj Dopsaj²

¹Faculty of Sport and Physical Education, Belgrade, Serbia and Montenegro

²Police Academy, Belgrade, Serbia and Montenegro.

Tactical, technical and functional demands of each position during game are a very significant factor for planning the training. The basic aim of this paper was to define the differences in basic and specific swimming characteristics of junior water polo players based on their position within the team. The sample of 31 players was divided into three groups: 1. players in wing positions (N = 19); 2. centers (N = 6); 3. backs (N = 6). 12 variables were the result of the following swimming tests: crawl 25m, 50m and 1500m, 25m crawl with ball, 25m back, specific swimming using legs 25m, legs crawl, breast and mixing and swimming 10x50m crawl. Cluster analysis has singled out five variables in which the observed groups differed. After the Student T-test, we obtained the difference between the groups. The players in wing positions are weaker than the others and that is not suitable for game.

Key Words: water polo, training, position within the team.

INTRODUCTION

Organisation of the training process is determined by various factors. A tactical, technical and functional demand of each position during game is a very significant factor for planning the training. Players, according to their morphological characteristics specialize for certain position, as the different position with their specific demands during the game influence the morphological aspect of a player (3). Differences with the players in different positions within the team can be greater (wing-back, wing-center), but they can be morphologically very similar (back-center) (3). Although this research followed the junior players, differentiation already exists since at the age of 18 they are in the final phase of specialization (1).

Tactical – technical demands of the game, which means a great number of swimming sections (4, 6, 7), especially in wing positions and great number of duels particularly in center and back position (2, 6, 7) caused the greatest differences exactly between these positions. The basic aim of this paper was to define the differences in basic and specific swimming characteristics of junior water polo players based on their position within the team.

METHODS

Sample and measuring methods

The sample of 31 players was divided into three groups: 1. players in wing positions left and right (N = 19) (Bm-179.99±4.07kg and Bw-75.72±5.54cm), group 2. are players who play in center positions (N = 6) (Bm-185.55±4.01kg and Bw-92.67±9.49cm) and group 3 are players who play in back positions (N = 6) (Bm-181.70±6.50kg and Bw-76.20±3.25cm).

The following swimming tests were performed:

— crawl 25m, 50m and 1500m (25m_{crawl}, 50m_{crawl}, 1500m_{crawl})
— 25m crawl with ball (25m_{crawlB})
— 25m back (25m_{back})

— Specific swimming using legs 25m, crawl stroke kicking, breast kick and egg beater kicking (25m_{crawlkic}, 25m_{legbre}, 25m_{egg})
— 10x50m crawl (10x50m_{crawl}) – 1 minute order

All tests were performed in the 50m swimming pool, the players started from water at the signal of the timekeeper, and tracks of 25m were measured by stopping the stopwatch when the head crossed the imaginary line of the finish of the distance. The obtained time was expressed in seconds with two decimals.

Variables

Each of the previously mentioned tests is of one variable, and another three index variables were singled out:

— Index of specific swimming efficiency (specific) – relation between 25m crawl and 25m crawl with ball
— Index of coordination of crawl technique (crawl_{armleg}) – relation between 25m crawl and 25m crawl stroke kicking
— Index of specific coordination of leg movement (legs_{crawlleg}) – relation between 25m crawl stroke kicking and 25m egg beater kicking

The values of the deduced variables were expressed in index numbers.

Methods of statistic elaboration

The overall set of 12 variables was subjected to Discriminant analysis and Student T-test (5). Data elaboration was done on a PC Pentium IV at 3.0 GHz applying statistic software programs STATISTICA (Stat Soft, Inc 2005) and EXCEL XP.

RESULTS AND DISCUSSION

The Table 1 gives the results of the discriminant analysis. On the general level, the differences are singled out in five variables - 25m back (25m_{back}), (F=3.826, p=0.034), specific swimming using legs crawl 25m (25m_{crawlkic}), (F = 6.068, p = 0.06), crawl 1500m (1500m_{crawl}), (F = 3.737, p = 0.036), 10x50m crawl (10x50m_{crawl}), (F = 5.666, p = 0.009) and index of specific coordination of leg movement (legs_{crawlleg}), (F = 3.963, p = 0.031) in which the observed groups differ.

Table 1. The results of discriminant analysis.

	Wilks Lambda	F	df1	df2	Sig
25m _{crawl}	0,962	0,555	2	28	0,580
25m _{crawlB}	0,913	1,33	2	28	0,281
25m _{back}	0,785	3,826	2	28	0,034
25m _{crawlkic}	0,698	6,068	2	28	0,006
25m _{legbre}	0,922	1,179	2	28	0,322
25m _{egg}	0,934	0,995	2	28	0,383
50m _{crawl}	0,942	0,866	2	28	0,432
1500m _{crawl}	0,789	3,737	2	28	0,036
1050m _{crawl}	0,712	5,666	2	28	0,009
specific	0,96	0,587	2	28	0,563
crawl _{armleg}	0,779	3,963	2	28	0,031
legs _{crawlleg}	0,866	2,167	2	28	0,133

After Student T-test it was realized that between groups 1 and 2 i.e. wing and center players (Tables 2 and 3) out of five singled elements in which the groups generally differed, only crawl 1500m (1500m_{crawl}) distinguished on the level of significance $p=0.041$.

Table 2. T-test for Equality of Means group 1-2.

	F	Sig	t	dt	Sig	Mean	Std. Error
					(2 tale d)	Difference	Difference
1500m _{crawl}	0,022	0,883	0,559	23	0,041	49,992	23,558
			0,576	8850	0,091	49,992	25,788

Between groups 1 and 3 i.e. wing and back players, the difference is in crawl (25m_{crawlkic}), ($p = 0.002$), crawl 1500m (1500m_{crawl}), ($p = 0.027$), swimming 10x50m crawl (10x50m_{crawl}) ($p = 0.003$) and coordination of crawl technique (crawl_{armleg}), ($p = 0.004$) (Tables 4 and 5).

Table 3. Group Statistic 1-2.

	Position	N	Mean (s)	SD (s)	St.Err. Mean
1500m _{crawl}	1	19	1288,597	46,792	10,734
	2	6	1238,607	67,166	23,338

Table 4. T-test for Equality of Means group 1-3.

	F	Sig	t	dt	Sig	Mean	Std. Error
					(2 tale d)	Difference	Difference
25m _{crawlkic}	0,245	0,625	3,453	23	0,002	3,165	0,916
			4,014	11171	0,002	3,165	0,788
1500m _{crawl}	4,759	0,04	3,267	23	0,027	61,560	25,998
			1,804	6,138	0,120	61,560	34,124
1050m _{crawl}	0,714	0,407	3,267	23	0,003	1,676	0,513
			2,679	6,562	0,034	1,676	0,625
crawl _{armleg}	0,721	0,404	-3,151	23	0,004	-5,00E-02	1,61E-02
			-2,771	7,067	0,027	-5,00E-02	1,83E-02

Table 5. Group Statistic 1-3.

	Position	N	Mean (s)	SD (s)	St.Err. Mean
25m _{crawlkic}	1	19	16,7058	0,7232	0,1659
	3	6	16,1050	0,6970	0,2845
1500m _{crawl}	1	19	26,0742	2,0575	0,4720
	3	6	22,9083	1,5478	0,6319
1050m _{crawl}	1	19	1288,5974	46,7923	0,4720
	3	6	1227,0367	79,3429	32,3916
crawl _{armleg}	1	19	0,5317	3,234E-02	7,420E-03
	3	6	0,5825	4,106E-02	1,676E-02

The difference was also determined between groups 2 and 1 in 25m back (25m_{back}), ($p = 0.025$) and specific swimming, legs 25m (25m_{legcrawl}), ($p = 0.030$) (Tables 6 and 7).

Table 6. T-test for Equality of Means group 2-3.

	F	Sig	t	dt	Sig	Mean	Std. Error
					(2 tale d)	Difference	Difference
25m _{back}	0,232	0,641	2,632	10	0,025	1,19	0,452
			2,632	9,586	0,026	1,19	0,452
25m _{crawlkic}	0,036	0,853	2,536	10	0,030	2,508	0,989
			2,536	9,673	0,030	2,508	0,989

Table 7. Group Statistic 2-3.

	Position	N	Mean (s)	SD (s)	St.Err. Mean
25m _{back}	2	6	17,2950	0,8606	0,35
	3	6	16,1050	0,6970	0,2845
25m _{crawlkic}	2	6	25,4167	1,8644	0,7611
	3	6	22,9083	1,5478	0,6319

CONCLUSION

Different positions in water polo have their specificities that should be responded to by the players who play in those positions. Analyzing general and specific swimming abilities of the players in different positions, we obtained the results showing the differences between the observed groups. Variables that singled out, 25m back (25m_{back}) ($F=3.826$, $p=0.034$), specific swimming using legs crawl 25m (25m_{crawlkic}), ($F = 6.068$, $p = 0.06$), crawl 1500m (1500m_{crawl}), ($F = 3.737$, $p = 0.036$), 10x50m crawl (10x50m_{crawl}), ($F = 5.666$, $p = 0.009$) and index of specific coordination of leg movement (legs_{crawlleg}), ($F = 3.963$, $p = 0.031$), point out the structure of activities in which the groups are different. Between the players in wing positions and those who play in center – group 2, the difference occurs in aerobic capacities i.e. crawl swimming 1500m (1500m_{crawl}). In the case of the tested sample, the players in center position have better aerobic capacity from the wing players table 3. which is unexpected form the tasks and demands of these positions, and is not characteristic for the teams on high training level (6,7). The difference between backs, group 3 and centers, group 2 reflects in the difference in specific speed 25m back (25m_{back}) and specific swimming using crawl stroke kicking 25m (25m_{crawlkic}) where the back position players are more dominant. Dominance of back players is expected with regard to their role in the game where they are expected to react and move fast especially in the phase of defence. Between group 1, players who play in wings and group 3 players who play in back position, the differences are in greater number of variables: in swimming legs crawl (25m_{crawlkic}), crawl 1500m

(1500m_{crawl}), crawl 10x50m (10x50m_{crawl}), and coordination of crawl technique (crawl_{armleg}). In all parameters, the players in back position are more dominant except in coordination of crawl technique (crawl_{armleg}). Such results show that general and specific swimming preparation does not suit to game necessities, i.e. that players in wing positions do not have adequate readiness according to the needs they should satisfy. With regard to the swimming sections and tactical tasks that players in wing positions have and related to the canters, and particularly related to backs, the level of their swimming readiness is insufficient (6).

The obtained results indicate that definitely there are differences in swimming features of the players in different positions. These differences are expected, but in relation to the tested sample are not regularly displaced according to the characteristics, and therefore coaches can, based on the obtained results, correct and direct further training work of each individual towards improvement of both general and specific swimming abilities in conformity with the demand of the position in which he plays.

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STRUCTURE OF GENERAL AND SPECIFIC SWIMMING ABILITIES IN JUNIOR TOP WATER POLO PLAYERS

Zoran Bratusa¹, Milivoj Dopsaj², Tadej Peranovic³

¹Faculty of Sport and Physical Education, Belgrade, Serbia and Montenegro

²Police Academy, Belgrade, Serbia and Montenegro

³Slovenian Water Polo Federation, Kranj, Slovenia.

Motor and tactical technical demands in playing water polo are increasing. The task of this research was to establish the most important factors which define the structures of general and specific swimming preparation of junior water polo players, Slovenian national team. 31 water polo players were tested: crawl 15, 25, 50 1500m, 25m crawl with head up 25m crawl with ball, 25m back, specific swimming by using legs 25m,

crawl stroke kicking, breast kick and egg biter kicking and 10x50m crawl, and 15 variables were derived. Four factors were set describing 78.068% of joined variability. The results indicate the existence of four various areas of preparation of swimmers. The first factor indicates that the general and specific speed of swimming, the second factor recognizes coordination swimming abilities of players; the third indicates specific leg movement, while in the fourth one swimming efficiency singles out.

Key Words: water polo, training, swimming tests.

INTRODUCTION

Motor and tactical technical demands in playing water polo are increasing (2), therefore the training demands from the early age are getting more complex in order to prepare the player to achieve top results through a quality training process. Control of the level of swimming preparation (3) from the aspect of evaluation of absolute and relative potential of energy mechanisms by swimming, as well as the level of swimming abilities of players with regard to the intensity zones are of great importance for training work. By defining methodological procedures, easily applicable in the training process in the framework of observation of the training system of players would enable easy evaluation and verification of the applied training methods (5), aimed at development of swimming preparation with regard to the sports conditions. The task of this research was to establish the most important factors which define the structures of general and specific swimming preparation of junior water polo players, members of Slovenian national team so that the method itself and the way of evaluation are easily applicable in the course of training by the coaches themselves.

METHODS

Sample and measuring methods

In order to determine the level of preparation of players, members of the national team, generation 1987 and younger, swimming abilities were tested. In the season 2004/05 31 players were tested.

The following tests were done:

- crawl 15, 25, 50 and 1500m (15m_{crawl}, 25m_{crawl}, 50m_{crawl}, 1500m_{crawl})
- 25m crawl with head up (25m_{crawlH})
- 25m crawl with ball (25m_{crawlB})
- 25m back (25m_{back})
- Specific swimming by using legs 25m, crawl stroke kicking, breast kick and egg biter kicking (25m_{crawlkick}, 25m_{legbre}, 25m_{egg})
- 10x50m crawl (10x50m_{crawl}) –1 minute. order.

Variables

Each of the above tests is one variable and another four variables were deduced:

- stroke index (SI) – (4)
- index of specific swimming efficiency (specific) – relation between swimming 25m crawl and 25m crawl with ball
- index of coordination of crawl technique (crawl_{armleg}) – relation between swimming 25m crawl and 25m crawl stroke kicking
- index of specific coordination of leg movement (legs_{crawlleg}) – relation between 25m crawl stroke kicking and 25m egg biter kicking

Methods of statistic elaboration

According to this, we got the overall of 15 variables and subjected them all to basic descriptive statistics where the following parameters were calculated: MEAN, SD, cV%, MIN and MAX, while the structure was defined by applying explorative factor analysis (5). Data elaboration was done on a PC Pentium IV at 3.0 GHz applying the statistic software program STATISTICA (Stat Soft, Inc 2005) and EXCEL XP.

RESULTS AND DISCUSSION

The results of the index of variation (cV%) show that they range among 3.55% for variable 25m crawl with head up (25m_{crawlH}) up to 10.54% for variable index of specific coordination of leg movement (legs_{crawllegg}). As the given values are in the range of less than 30%, it can be asserted that, the results are reliable and can be used for further analysis and valid interpretation.

Table 1. Descriptive Statistics.

	25m _{crawl}	25m _{crawlB}	25m _{crawlH}	50m _{crawl}	15m _{crawl}	25m _{back}	25m _{bre}	25m _{egg}	25m _{armleg}	25m _{crawlkic}	1500m _{crawl}	10_50m _{crawl}			
Mean(s)	13.79	14.27	14.02	29.22	7.57	16.70	0.55	25.33	0.92	0.97	24.69	27.77	1.55	1267.1	34.23
SD(s)	0.52	0.56	0.50	1.28	0.44	0.81	0.04	2.25	0.10	0.03	1.51	1.85	0.14	60.69	1.22
cV%	3.78	3.90	3.55	4.37	5.77	4.68	7.82	8.86	10.54	2.93	6.11	6.68	9.26	4.79	3.57
Min(s)	13.09	13.13	13.01	27.29	5.57	15.57	0.47	21.20	0.76	0.91	22.20	24.41	1.30	1139.70	31.20
Max(s)	15.13	15.57	15.16	31.48	8.41	18.42	0.63	30.73	1.12	1.04	27.50	32.13	1.18	1385.20	26.28

Table 2. Total Variance Explained.

Component	Initial Eigenvalues		Extractions Sums of Squared Loadings			Rotation Total	
	Total	% of Variance	Cumulative %	Total	% of Variance		
1	5,394	35,958	35,958	5,394	35,958	35,958	4,702
2	2,617	17,449	53,407	2,617	17,449	53,407	3,126
3	2,236	14,906	68,313	2,236	14,906	68,313	2,193
4	1	9,755	78,068	1,463	9,755	78,068	3,087
5	0,984	6,557	84,625				
6	0,627	4,179	88,804				
7	0,505	3,370	92,174				
8	0,4	2,664	94,838				
9	0,244	1,628	96,466				
10	0,218	1,453	97,919				
11	0,157	1,048	98,966				
12	0,128	0,853	99,819				
13	,554E-02	,170	99,989				
14	,404E-03	9,357E-03	99,998				
15	,566E-04	1,711E-03	100,000				

Factor analysis by means of using Oblimin criterion defined four factors that describe the overall of 78,068% (Table 2.) of joined variability, on the statistically significant level of reliability (KMO measure of sampling adequacy - 0.748, Bartlett's test of Sphericity - F = 2431.76, p = 0.000). In the explained variability, the first factor saturated 35,958% (Table 2), and consisted of the following variables: 25m_{crawl}-0,894, 25m_{crawlB}-0,890, 25m_{crawlH}-0,845, 50m_{crawl}-0,770 (Table 3.). The given structure of factors indicates that the greatest difference between players is exactly in the general and

specific speed. The second factor that saturated 17,449% (Table 2) consisted of the following variables: crawl_{armleg}-0,942, 25m_{crawlkic}- -0,894, legs_{crawllegg}- -0,768 (Table 3.), and it recognize the difference in coordination swimming features of the players. The third factor saturated 14,906% (Table 2.) of the explained variance defining the following variables: 25m_{legbre}-0,924, 25m_{egg}-0,794 (Table 3.). The given structure clearly points that the ability describing a specific legwork is separated. The fourth factor with 9,755% (Table 2.) of the explained variances was defined by the following variables: SI-0,876, 1500m_{crawl}- -0,769, 1050m_{crawl}- -0,711 (Table 3.). Based on the selected structure, the given factor can be defined as efficiency of swimming by using crawl technique in aerobic and anaerobic strain regime.

Table 3. Structure Matrix.

	Component			
	1	2	3	4
25m _{crawl}	0,894			-0,476
25m _{crawlB}	0,890	-0,424		
25m _{crawlH}	0,845			
50m _{crawl}	0,770			-0,503
15m _{crawl}	0,690		-0,476	-0,399
25m _{back}	0,633		0,339	-0,413
crawl _{armleg}		0,924		
25m _{crawlkic}	0,432	-0,894		
legs _{crawllegg}	0,369	-0,768	-0,483	
specific		0,563		-0,491
25m _{legbre}			0,924	
25m _{egg}			0,794	
SI				0,876
1500m _{crawl}	0,396			-0,769
1050m _{crawl}	0,643	-0,407		-0,711

CONCLUSION

The obtained results indicate that it is possible to estimate the level of swimming preparation of players in the observed sample with regard to the structure of general and specific swimming abilities (1). It was also determined that there were great differences with regard to influence of separated factors in function of measuring area i.e. used set of tests. The first factor indicates that speed of swimming, achieved both by general and specific water polo techniques, (25m_{crawl}-0,894, 25m_{crawlB}-0,890, 25m_{crawlH}-0,845, 50m_{crawl}-0,770) (Table 3) is the ability that defines qualitative swimming preparation of water polo players i.e. the ability that determines most the difference of swimming preparation between players in the given age category and competition level. Such results point the way to continue the training process, i.e. that it is through training process that these features of players should be developed, in order to increase the level of competition preparation of the whole team by raising the individual swimming abilities. The second factor, which recognizes coordination of swimming abilities of players (crawl_{armleg}-0,942, 25m_{crawlkic}- -0,894, legs_{crawllegg}- -0,768) (Table 3) indicates that not all the players are on the satisfactory coordination lever, offering thus also some space for progress of individuals and therefore of the whole team. Great dynamics of position changes during the game, realization of various techniques of movement with or without a ball, requests that the players must be well trained (educated) with trained coordination, in order to successfully play water polo. The third factor indicates specific leg movement (25m_{legbre}-0,924,

25m_{egg}-0,794) (Table 3), which is very significant in water polo games, so the improvement of these features also improves the level of playing readiness of the players or the team is improved. The fourth separates the swimming efficiency of crawl technique in aerobic and anaerobic working loading (SI-0,876, 1500m_{crawl}-0,769, 1050m_{crawl}-0,711), (Table3). The most dominant technique in the course of water polo game is crawl, and during a game players swim between 900 and 1300 meters, a player realizes about 60 to 80 different combinations of acceleration or swimming of short distances between 5 to 20 meters (7, 8). Those players who swim crawl more efficiently i.e. have better crawl swimming technique, can more easily stand the swimming efforts during the game and trainings that are realized in both aerobic and anaerobic work strains. Besides, the difference in swimming indicates insufficient or inadequate training. Therefore, basic training work to be carried out in clubs is not everywhere on the desired level.

On the other hand, limited number of players for selection in the national team imposes the urge to intensify training in clubs, in order to decrease the obtained differences in swimming abilities (7). That would increase the general level of readiness of the members of the national team and lead, consequently, to easier overcoming of technical – tactical tasks and better results of the national team.

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FREESTYLE RACE SUCCESS IN SWIMMERS WITH INTELLECTUAL DISABILITY

Daniel J. Daly¹, Ingi Einarsson², Peter Van de Vliet¹, Yves Vanlandewijck¹

¹K. U. Leuven, Department of Rehabilitation Sciences, Belgium

²Iceland University of Education, Reykjavik, Iceland.

Athletes with intellectual disability (ID) competing at international level show lower levels of explosive strength and cardiovascular fitness when compared to age matched trained persons. Behavioural characteristics such as motivation, and ability to deal with stress are more difficult to examine. In the 100-m freestyle race Paralympic competitors with loco-motor disability all use similar race speed and stroking strategies. But do trained and experienced swimmers with ID also generally adapt these patterns? Video race analysis data was collected on 81 elite male swimmers including ID athletes, loco-motor disabled, visually impaired as well as able bodied. In long course races there is a typical race pattern used by all swimmers with sufficient race experience regardless of absolute performance level. Individual race tactics do not generally determine the outcome.

Key Words: swimming, freestyle, intellectual disability.

INTRODUCTION

Race speed differences among Olympic and Paralympic swimmers with intellectual disability (ID) are determined by physical aptitude, fitness (training), use of correct techniques (knowledge) and adapting optimal race patterns (experience) (3). Furthermore suitable nutrition and rest as well as an environment conducive to proper training are necessary to achieve a maximal level of performance. Potential participants must show impaired intellectual functioning and limitations in adaptive behaviour according to criteria set by the World Health Organisation and the American Association of Mental Retardation. Previous study of ID athletes participating at world championship competitions (basketball, football, swimming, table tennis, and track and field) has shown that in comparison to population data, both males and females score better for flexibility and upper body muscle endurance, but have similar or lower values for running speed, speed of limb movement, and strength measures (4). Compared to age-matched physical education students, male athletes with ID score better for running speed and flexibility, and poorer for strength. Female athletes with ID are not different from able-bodied individuals for flexibility, running speed and upper body muscle endurance, but score less well for strength measures. Athletes with ID also have poorer cardio respiratory endurance capacity compared to sportive peers without ID. Within this group of athletes, swimmers were younger, more flexible, had better cardiovascular fitness in a running test but scored lowest in explosive leg strength.

Sport specific behavioural characteristics such as motivation and ability to deal with stress (experience) are more difficult to examine than physical characteristics. These might, however, be reflected in deviating race speed or arm movement patterns. In the 100-m freestyle race almost all Paralympic competitors with a loco-motor disability use similar speed and arm stroking race patterns (1). The question at hand hence is, do trained and experienced swimmers with ID also generally adapt these patterns?

METHODS

Video competition analysis data was collected at the 2004 Global Games World championships for swimmers with ID and from 2000 Sydney Paralympic Games finalists including swimmers with ID (class S14), loco-motor disability (classes S10 + S9) and visual impairment (classes S13 + S12). Further

reference data was available from finalists at the 2000 Sydney Olympic Games, the 2000 Australian Olympic trials, the 2005 European indoor championships (2) and the 2005 Scandinavian youth championships. In total data on Clean Speed (CSS), Stroke Rate (SR) and Stroke Length (SL) was available for four 100-m freestyle race sections in 81 male competitors. In addition starting, turning, and finishing speed was measured. Furthermore indexes were determined relating starting, turning, and finishing speed to swimming speed in the adjacent race section. Relative race time (percentage) was calculated for each race segment. A point score was also given to performance in relation to the group (class) world record (=1000pts). Descriptive statistics, ANOVA, and Spearman correlations were calculated. Race speed and arm movement patterns were defined by the relative change in these parameters between adjacent race sections. Groups of swimmers with similar race speed patterns could be isolated using Cluster Analysis including these speed changes.

RESULTS

Performance and race analysis results are shown for the Global Games, 2005 European indoor championships and 2005 Scandinavian youth swimmers (short course) in table 1 and for the Sydney 2000 Olympic and Paralympic Games (long course) in table 2. For lack of space not all groups used in this analysis are shown. Cluster analysis of the within race speed changes resulted in only one large race speed cluster (n=72). Eight additional clusters were formed containing 9 extra swimmers indicative of unusual race speed patterns. These were temporarily set aside. Five groups were then formed:

1) loco-motor impaired ($M = 58.95s; \pm 2.33, n=16$), 2) visually impaired ($M=58.21s; \pm 1.24, n=16$), 3) ID swimmers ($M=57.73s \pm 1.79, n=11$), 4) international able bodied (AB) swimmers ($M = 48.68s \pm 0.92, n=21$) and, 5) youth international AB swimmers ($M = 52.69s = 0.99, n=8$). Within race speed changes between 4 segments were $-3.2\% (\pm 2.45)$, $-4.3\% (\pm 2.41)$, and $-4.6\% (\pm 2.53)$ as the race progressed. Only ID swimmers lost significantly more speed in the middle of the race than International AB participants ($F=3.17, p < .019$). A decreased loss of speed between segments 2 and 3 was significantly related to race success (.58).

There were no significant differences among groups in within race changes for either SR or SL. Mean changes in SR were $-6.80\% (\pm 4.91)$, $-1.91\% (\pm 5.02)$, and $-1.76\% (\pm 4.63)$ and for SL $3.17\% (\pm 4.21)$, $-2.59\% (\pm 4.24)$, and $-2.96\% (\pm 4.74)$ respectively as the race progressed. Within race changes in SR were significantly related to changes in Clean speed (.36, .54 and .33). Less reduction of SR resulted in less reduction of swimming speed. No similar relationship was found for SL. Based only on Sydney results there are also no differences between groups in the percentage of time spent in any race swimming section or starting, turning, or finishing. The various results collected in short course differed slightly in starting distance so that it is not advisable to compare these types of results too closely.

DISCUSSION

Race speed, stroke rate, and stroke length patterns of swimmers with ID do not appear to be different than any other group of experiences competitive swimmers. Swimming speed decreases as the race progresses in a stable way. Stroke rate shows a strong decrease initially and then stabilises and in gen-

eral SL increases at the beginning of the race and then declines. Although not significant SR decreases are greater in ID swimmers although this is not necessarily reflected in the speed changes. Apparently it seems that there are some slight differences when swimming in short course or long course pool which need further investigation

Of the 9 swimmers not fitting the large cluster, 3 were ID swimmers, 2 were youth Internationals and 3 were AB elite. While 6 of these swimmers were observed in short course races only 33% of all swimmers were analyzed in short course events. The unusual race patterns of the 3 ID swimmers not included in the main cluster as well as the more conform patterns of the 3 other ID short course finalists were verified during preliminary heat swims. No ID swimmers participating in the long course competition at the Sydney Paralympics demonstrate any specific race pattern deviation. This disproportion looks therefore to be a trait of short course races rather than a feature of ID swimmers.

Table 1. Means, Standard Deviations, and within race speed changes (%Δ) for competition analysis data in world championship participants with intellectual disability (Global Games: 2004), 2006 European Indoor swimming championships, and Scandinavian youth championships. Competitions held in short course (25-m) pool.

	Global Games (n=6)			European (n=8)			Indoor Scandinavian (n=10)			Youth
	M	SD	%Δ	M	SD	%Δ	M	SD	%Δ	
Time (sec)	57.78	2.19		47.7	0.58		52.67	0.89		
Class point	876	97		912	34		869	45		
8th place (pt)	733			874			823			
Index ⁽¹⁾										
Start	128.03	8.18		119.44	5.07		118.21	7.46		
Turn1	112.37	10.13		111.98	1.52		109.11	2.03		
Turn2	110.14	5.19		110.23	2.19		109.44	3.74		
Turn3	110.83	2.50		112.68	2.20		108.89	3.12		
Finish	103.16	2.61		112.44	4.99		103.70	2.80		
CS Speed (m/s)										
Section 1	1.77	0.08		2.09	0.08		1.91	0.14		
Section 2	1.66	0.09	-6.67	1.99	0.02	-4.99	1.79	0.10	-6.45	
Section 3	1.60	0.06	-4.11	1.93	0.05	-2.84	1.73	0.06	-3.52	
Section 4	1.05	0.07	-6.76	1.82	0.03	-6.11	1.74	0.19	-2.53	
Stroke Rate (str/min)										
Section 1	55.14	5.70		56.62	2.40		54.18	6.20		
Section 2	53.65	5.10	-2.70	53.12	3.10	-6.70	52.69	5.20	-3.20	
Section 3	50.68	5.00	-5.90	52.80	2.80	-0.50	52.14	5.40	-1.90	
Section 4	49.05	2.80	-3.10	51.75	2.80	-2.10	49.60	4.70	-5.70	
Stroke Length (m)										
Section 1	1.95	0.22		2.23	0.17		2.15	0.33		
Section 2	1.88	0.21	-3.90	2.26	0.12	1.50	2.07	0.24	-4.44	
Section 3	1.92	0.23	1.81	2.21	0.12	-2.32	2.02	0.22	-3.16	
Section 4	1.84	0.17	-3.64	2.12	0.10	-4.00	2.05	0.23	1.02	

(1) Index = start, turn or finish speed/adjacent segment Clean Swimming Speed.

Table 2. Means, Standard Deviations, and within race speed changes (%Δ) for competition analysis data in Sydney 2000 Olympic and Paralympic swimming finalists (n = 8) with Intellectual Disability (S14), visual impairment (S13) and loco-motor disability (S10) (Competitions in long course 50-m pool).

	S14			S13			S10		
	Mean	SD	%Δ	Mean	SD	%Δ	Mean	SD	%Δ
Time (sec)	48.94	0.40	37.63	1.13	39.81	1.34	51.27	1.34	
Class position	914	22.6	928	19.4	896	43.9	944	22.7	
100m (sec)	900		916		891		788		
Start (Sec)	12.12	0.26	12.44	0.21	12.17	0.28	12.04	0.31	
Turn 1 (Sec)	14.48	0.30	14.67	0.26	14.39	0.30	14.40	0.18	
Finish (Sec)	2.09	0.11	2.1	0.12	2.16	0.24	2.11	0.22	
Start Index*	150.58	2.79	148.58	2.40	150.64	4.78	157.26	2.94	
Turn Index	107.10	3.47	108.80	2.71	107.77	2.44	109.11	0.77	
Finish Index	47.76	1.93	46.29	2.40	46.96	2.97	46.47	1.4	
Time Section 1 (Sec)	9.14	0.14	6.67	0.21	6.76	0.27	6.89	0.11	
Time Section 2 (Sec)	17.46	0.11	17.46	0.24	17.48	0.21	17.54	0.28	
Time Section 3 (Sec)	18.41	0.29	18.44	0.18	18.34	0.22	18.26	0.18	
Time Section 4 (Sec)	22.18	0.2	21.79	0.18	22.21	0.12	21.98	0.42	
Speed Section 1 (sec/m)	2.10	0.01	1.76	0.01	1.77	0.07	1.77	0.04	
Speed Section 2 (sec/m)	2.02	0.02	-1.67*	1.72	0.01	-1.24	1.71	0.01	-1.12
Speed Section 3 (sec/m)	1.94	0.03	-2.17*	1.62	0.01	-0.41	1.63	0.01	-1.47
Speed Section 4 (sec/m)	0.97	0.03	-0.99*	1.09	0.01	-2.1	1.26	0.07	-1.1
100m Section 1 (sec/m)	10.01	0.39	10.28	0.24	10.24	0.22	10.42	0.30	
100m Section 2 (sec/m)	11.47	0.01	-0.02*	11.44	0.06	-7.10	11.41	0.14	-0.03
100m Section 3 (sec/m)	10.90	2.77	-1.44	11.49	4.47	-12.11	10.91	0.30	-12.41
100m Section 4 (sec/m)	10.46	0.02	-0.09	10.52	1.76	-2.43	10.47	0.46	-1.98
100m Section 1 (sec)	2.11	0.11	1.89	0.26	2.02	0.17	1.93	0.12	
100m Section 2 (sec)	2.26	0.14	2.07*	1.96	0.19	3.62	2.11	0.10	4.01
100m Section 3 (sec)	2.28	0.13	-1.87*	1.96	0.12	-2.29	2.00	0.14	-4.26
100m Section 4 (sec)	2.21	0.17	-1.89*	1.90	0.18	0.96	1.98	0.17	-2.73

*S13 Index = start, turn or finish speed adjustment against C Swim Benchmark Speed.

It now appears that at least in long course races there is a typical race pattern used by all swimmers with sufficient race experience regardless of the absolute performance level. This is not influenced by direct external factors. Class S13 (see table 2), for example, are legally blind. Where persons without visual impairment can read normal newsprint at 1m distance, these athletes could only read this at 10cm. So the ability e.g. to “see” the opposing swimmer or the pool surroundings may not be as important as experience (movement rhythm, feeling of the water and perceived exertion) in employing a suitable race pattern. This further indicates that there is little tactical component to this particular race which may be an advantage to ID swimmers. Moreover a race is always conducted in the same manner and presently at high level competition problems such as poor lighting, cold or warm water and slow (turbulent) pools are somewhat a thing of the past. There are few “surprises” if the preparation is sufficient leading up to the race. So a large number of extraneous factors are eliminated resulting in a race speed pattern that is distinct to the race at hand and not the individual.

Another factor supporting the hypothesis of only one general race tactic in the 100-m freestyle is the fact that there are no differences between groups in the amount of time spent starting or turning. Neither ID athletes nor those with visual impairment have more trouble than other athletes in turning for example. To confirm this further work is needed to examine the women competitors as well as heat swims, however. Closer study is also required on the differences between long and short course races. For visual impaired and ID athletes addition turns might add to the problems encountered.

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CHALLENGES OF USING CRITICAL SWIMMING VELOCITY. FROM SCIENTISTS TO COACHES

Jeanne Dekerle^{1,2}, Patrick Pelayo¹, Michel Sidney¹, Gary Brickley²

¹Human Movement Studies Laboratory, University of Lille 2, France
²Chelsea School, University of Brighton, United Kingdom.

So far, a few studies have been conducted on the Critical swimming velocity concept. The current available knowledge suggests there is merit in using CV for training. The model offers potential to swimming in that it is non-invasive and easy to administer. The CV concept appears as a useful tool for setting training intensities, monitoring training effects, and predicting performances. All these applications are reviewed in the present article.

Key Words: critical velocity, usefulness, assessment, training.

INTRODUCTION

The d-t relationship is almost strictly linear in swimming (Figure 1; Panel A; Equation 1). It has been verified in groups of trained adults (23) and children (9, 19).

Equation 1: $d = a + CV \times t$

Its slope has been called Critical velocity (CV) referring to previous works done on the muscular capacity (see (1, 11) for review). CV is also represented by the asymptote of the velocity-time relationship and is mathematically defined as the velocity that can be maintained (in theory) indefinitely (Figure 1; Panel B).

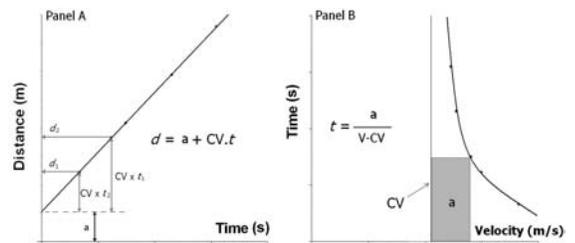


Figure 1: Schematic of the 2-parameter model (d-t relationship - Panel A; v-t relationship - Panel B). On Panel B is represented the distance (d1 and d2) covered during to events and equal to the sum of a plus the product of CV and time (t1 and t2).

The CV determination has been shown to be reliable even if exhaustion times are variable (13, 22) and physiological responses at CV have also been shown in swimming, to be reproducible (3). Further research is required investigating the

CV concept but current available knowledge suggests there is merit in using CV for training. The model offers potential to swimming in that it is non-invasive and easy to administer. When being aware of its underlying assumptions (see complementary article; Deckerle et al.), the CV concept seems a useful tool for setting training intensities, monitoring training effects, and predicting performances.

PHYSIOLOGICAL MEANING OF CV

CV has firstly been thought to correspond to a sustainable intensity and has been compared to parameters such as the maximal lactate steady state (MLSS; highest intensity that can be maintained without any drift in the blood lactate concentration ([La])) or the onset of blood lactate accumulation (OBLA; intensity corresponding to a 4-mmol.L⁻¹ of [La]). Wakayoshi et al. (24) and Brickley et al. (3) obtained steady [La] values during several 400-m blocks performed at CV (around 3-4 mmol.L⁻¹). But the 30-45 sec of rest enabling blood samples to be taken between the blocks could have helped the swimmer keeping his motivation, limiting the drift of [La] and maintaining a 'relatively' good efficiency. Stroking parameters have indeed been shown to change, with progressive stroke rate increases and stroke length decreases within and between the 400-m blocks (3).

Most authors today agree that CV does not correspond to a sustainable intensity. In fact, swimmers can hardly maintain their CV for longer than 35 min (unpublished data from our laboratories) and CV has been shown to be close to the velocity of a 30-min test (8) and higher than MLSS (7) and OBLA (9, 20, 24, 25). These results are in agreement with results obtained in cycling reporting drifts of heart rate, [La], and VO₂ with values closed to their maximal at Critical Power/Velocity (4).

CV is today defined as the upper limit of the heavy intensity domain, i.e. the highest intensity that does not allow VO₂max to be attained during a constant load exercise (12). Above CV, because of the slow component phenomena, VO₂max should be elicited. This definition of has not yet been directly verified in swimming but is in line with several findings reported in the literature in swimming. CV is lower than the end velocity of an incremental test, traditionally identified as the maximal aerobic velocity (around 92-96% of the 400-m velocity). It is highly correlated to OBLA (23, 24, 25), the average 400-m velocity (23, 24, 25), and MLSS (7). The first belief that CV was sustainable for a very long period of time was a misinterpretation of the mathematical (and not physiological) definition of CV, i.e. the intensity that can be maintained indefinitely (asymptote of the velocity-time relationship).

SETTING TRAINING INTENSITIES

CV allows demarcating two different intensity domains and should be used as a reference to set training intensities. The 400-m pace is usually used by coaches for this purpose. However, two swimmers with similar performances on 400 m can have different aerobic potentials (Figure 2). One can swim a 1500 m quicker than the other one (and so, for short races). The physiological stress to exercise of long duration will be different for the two swimmers. It is important to properly individualise training loads to optimise the physiological adaptations while avoiding overtraining especially when accuracy in the definition of the training loads is required as higher levels of performance.

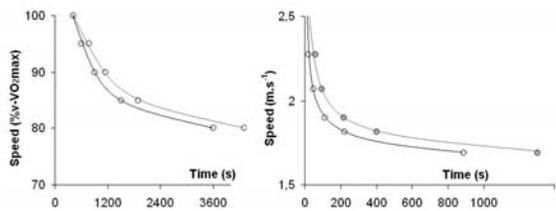


Figure 2: Schematic of the speed-time relationship of two different swimmers having different aerobic potentials.

Using CV for aerobic training programs offers great potential. It allows better setting of continuous, long and short interval training for each. Continuous training (2000-3000m) and long interval training at and below CV would induce great lactic acid production leading to accumulation of H⁺ that would be buffered and La⁻ that would be oxidised in different body cells. An example of long interval training could be 6 to 10 x 400m swum at CV with 15-sec rest. Indeed, several 400-m blocks performed at CV can be swam with steady [La] values (around 3-4mmol.L⁻¹) when separated by 30-40s of rest (3). Among all acute adaptations, we could expect a great improvement of the buffering capacity and oxidative potential of several body cells on top of the muscular ones (10). Central and peripheral adaptations occur with training performed around CV but it can be expected that the peripheral adaptations induced by swimming at and below CV would be less predominant with the increase in the intensity, the central adaptations becoming even more important. Adequate long and short interval training above CV (20-30 x 100m at 110% CV, 30-s rest; 1min at 120% CV, 1min rest for 20 min) would enable VO₂max (very high heart rate and stroke volumes) to be solicited and maintained for a very long time. This could lead to optimise the improvement of VO₂max over time as suggested by Billat and collaborators (2). The short interval training is also of great interest as it allows swimming at high race paces while challenging the aerobic potential (200- up to 1500-m pace in this case). Training at race pace is important, especially in swimming where swimming coordination (21), energetic cost (5), and technical efficiency are changing depending on the velocity. Short interval training would enable to focus on the swimming techniques whose swimmers should attempt to maintain efficient while fatigue progressively develops during such long aerobic work performed around CV.

It has also been observed a drop of stroke length when swimming above the lactate threshold (17) or MLSS (6). Accordingly, when swimming several 400-m blocks at CV with steady [La] values, stroke parameters change, with progressive SR increases and SL decreases within and between the 400-m blocks (3). This leads to suggest that swimmers should focus on their stroke length (SL) / stroke rate (SR) ratio when swimming around CV in order to carry out a good qualitative technical work. Coaches should make an attempt to determine at which velocity and in which extend the SL and SR change. They could then train swimmers either to maintain both velocity and one of the other stroke parameters despite the increase in fatigue, or to maintain SL while increasing SR for a faster swim. As explained above, it is known that training at race pace is of importance for technical aspects of the strokes. Therefore, this training strategy relying on the multiple combi-

nations linking the stroke parameters ("task constraint" strategy) should be performed at any velocity of the race spectrum.

MONITORING TRAINING EFFECTS AND PREDICTING PERFORMANCE

The use of the CV concept to monitor training effects and predict performance still has to be investigated. A few studies have shown the 2-parameter model to be affected by training (14, 15). Swimming aerobic training has a positive effect on CV while the change in the intercept is consistent with the training performed (16). Indeed, the value of the intercept has been shown to be more affected by low variations of exhaustion times than CV (22) and its physiological meaning has not been yet confirmed (8, 18). Therefore, we would suggest being prudent when interpreting its value and change over training. Plotting the *d-t* relationship would enable to monitor the effects of training on CV over a season (Figure 3).

When knowing the equation of the *d-t* relationship, it seems possible to predict swimming performance. Again, this should be confirmed or infirmed by further research. However, because of the good linearity of the relationship, coaches can try to predict performance as long as they are ranging between around 2 and 30 min (see complementary article; Dekerle et al.).

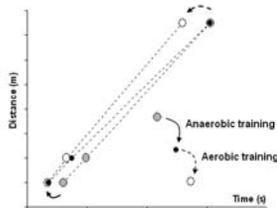


Figure 3: Effects of aerobic and anaerobic training on the *d-t* relationship.

CONCLUSION

The actual knowledge on the application of the CV concept seems sufficient to underlie its interests for training. The *d-t* relationship seems a useful tool for setting training intensities, monitoring training effects, and predicting performances. However, "luckily" for researchers, further research is required to confirm its meaningfulness in swimming (responses at and above CV) and usefulness for training (among all, effects of training at intensities around CV, effects of training on the *d-t* relationship, kicking vs full stroke CV, prediction of performance). Almost all the studies conducted on the Critical Swimming Velocity have been conducted on trained swimmers whose 40-m performance ranged from 72-84% of the world record. It can be wished that the concept will soon be tested on groups of elite swimmers.

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THE PROBLEM OF PEAKING IN VIEW OF EVIDENCES FROM THE ATHENS OLYMPIC GAMES

Vladimir Issurin¹, Leonid Kaufman¹, Gilad Lustig¹, Gershon Tenenbaum²

¹Elite Sport Department at the Wingate Institute, Netanya, Israel

²Florida State University, Department of Educational Psychology, Florida, USA.

The present study tested the assumption that several crucial factors, such as duration of the final stage preparation (FSP), gender, age, selection procedures, swimmers' ranks, swimming stroke and distance account for swimming time variance in the 2004 Athens Olympic competition. A total of 424 events performed by 301 Olympic swimmers were analyzed to obtain the relative performance gain (RPG%) that was computed as the differences between the entry swimming results and swimming time in the Olympic competition. The average RPG% gain equaled 0.58% ($SD = 1.13\%$), indicating performance decline, embracing 68.2% of all the swimming events. Only two categories of competitors, the medal winners and swimmers ranked 4-8, surpassed their previous entry time; one-way ANOVA revealed significant ($p = .04$) superiority of the swimmers who were selected rigorously over swimmers selected liberally.

Key Words: peaking, olympic performance, tough and liberal selection.

INTRODUCTION

The Olympic Games, as the athletic, social and cultural mega-event of our times, provide a unique experience, which require multi-disciplinary analysis and consideration, which are important both for science and practice. Such analysis is of particular importance when aiming at achieving the best individual outcome in a specific Olympic event. Thus, peaking obtaining by the best athletic performance at a particular moment, is of pri-

mary importance for any athlete. Peaking was usually considered with regard to tapering (1, 8); the wide spread approach presupposed evaluation of peaking by means of comparison of pre-taper and post-taper results. Such type of statistical treatment led to very impressive performance improvement ranging between 1 to 6.8% (7, 8). Another estimation approach being realized in a few recent studies prescribes comparison of results obtained during selection trials and ultimate achievements on Olympic Games' performances (11, 12). The latter approach does not consider taper, as the short-term period, when the workloads are reduced, but rather the Final Stage of Preparation (FSP) as the specific period, when a selected and specially organized group (team) executes a purposeful training program directed at the targeted competition. Therefore, the quality of the peaking process can objectively be assessed by comparing the results of the beginning and the end of the FSP. Competitive swimming, as an Olympic sport with absolutely reproducible standard conditions and reliable and measurable performance evaluation provides a unique opportunity to study peaking.

METHODS

Subjects

301 Olympic swimmers (153 males and 148 females) representing 24 National teams, aged between 15-33 years, took part in a total of 424 events. Selection of the swimmers for analysis was based on the following criteria: (a) taking part in the Olympic trials and Olympic Games in the same event, or (b) obtaining an official result in competitions before entering the FSP, and taking part in the Olympic Games in the same event.

The Final Stage Preparation was operationalized as a time period between the selection Olympic trials, or another competition where an athlete obtained his/her official entry time. Therefore, the length of the FSP varied between 29 (USA) – 151 (Italy) days. The training programs of the teams varied significantly: the teams with a relatively long FSP took part in several competitions including European Championships, and other international meetings. All swimmers practiced a drastic workload reduction prior to the Olympic events – taper – lasting usually within the range of 10-25 days.

Performance results' analysis. All competitions were organized in accordance with the regulations of the International Swimming Federation (FINA) exclusively in the Olympic standard 50-m pool. The results were registered by the electronic "Omega" system, and were collected from the official protocols of Olympic Trials and the Athens Olympic Games. In both cases the best result of the corresponding swimmer was taken for analysis. The absolute and relative differences between the entry swimming results obtained during trials or another competition, and during the Olympic competition were calculated. Thus the main indicative estimate called Rate Performance Gain (RPG %) was obtained. The following factors were used as independent variables:

- *selection mode* – two modes were considered: *tough selection*, which has been used by the world-leading countries with official Olympic trials, and *liberal selection* practiced mainly by teams with small number of world-ranked swimmers, which can meet Olympic criteria during the whole Olympic year, and even earlier;

- *FSP duration* – 29-33, 34-90, 91-130, and 130 and more days were accounted;
- *stroke types and events* - all data were analyzed with regard to four swimming strokes and individual medley; twenty six individual events were analyzed, namely: 50, 100, 200, 400-m,800 and 1500-m in freestyle; 100 and 200-m in backstroke, breaststroke and butterfly; 200 and 400-m in individual medley;
- *gender and age* - gender and three age categories: young, 15-19 yrs; adults, 20-24 yrs; and veterans – 25 yrs and more;
- *personal athletic ranking* - four categories of Olympians were considered: medal winners; swimmers obtaining 4th – 8th places; swimmers ranked 9th – 16th places; and swimmers ranked 17th place and lower.

Statistical procedures

Descriptive statistics were computed for RPG% with respect to 24 National assignments, stroke-type, swimming distance, swimmer’s rank, gender, and FSP duration. Analysis of variance (ANOVA) and cluster linear regression after logistic transformation procedure were employed to capture the factors determining RSPG% in the Olympic swimming competition.

RESULTS

Fig. 1 displays estimates of RPG% and duration of FSP in world-leading countries. The mean RPG% among all 24 Nations equaled 0.58% (*SD* = 1.13%); this indicates general trend of performance decline that embraces 68.2% of analyzed events. The graph shows the teams with minimal average performance decline (the least values of RPG%); and the FSP duration in these teams varies between 28 – 109 days (Poland, USA, Japan and Germany). The general trend of FSP duration indicates that the shortest FSP is beneficial; in fact this tendency didn’t reach significance.

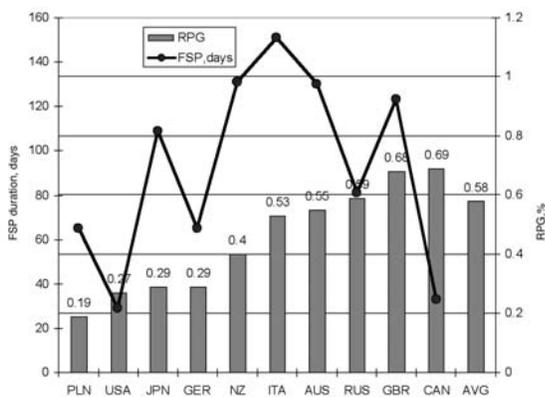


Figure 1. Rate Performance Gain and duration of Final Stage Preparation in several National teams.

The analysis revealed two statistically significant facts: one-way ANOVA considering nations with “tough selection” vs. “liberal selection”, revealed significant (*p* = .04) superiority of the swimmers who were selected rigorously over swimmers selected liberally: their RPG equaled 0.46 vs. 0.84 respectively. Further more, medal winners and swimmers ranked 4-8 were

the only one to obtain negative RPG, meaning enhanced performance during the Olympic competition (Figure 2).

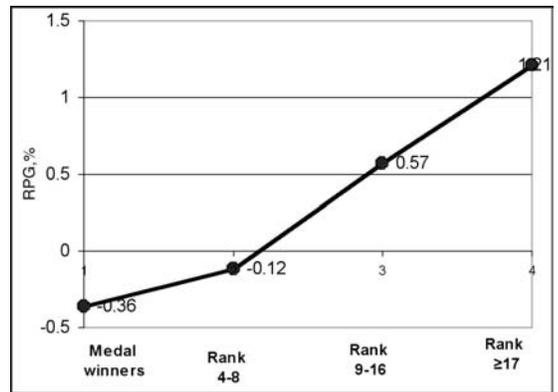


Figure 2. Relationship between RPG and athletes' rank.

No gender difference was found in RPG%: 0.66 vs. 0.50 respectively (*p* ≥ .05). Comparison of three age categories didn’t reveal any visible superiority of one over the other; the RPG% values of “youngsters”, “middle age”, and “veterans” equaled to 0.74, 0.51 and 0.59 respectively. Stroke Type failed to reach significance (Table 1). Similarly, no significant differences were found for swimming distance (Table 2).

Table 1. Mean values and SD's of RPG by Stroke Types.

	Crawl	Backstroke	Breaststroke	Butterfly	Medley
n	170	63	70	61	53
M _{RPG%}	0.68	0.58	0.47	0.34	0.65
SD _{RPG%}	1.20	1.21	0.96	1.00	1.14

Table 2. Mean values and SD's of RPG by distance.

	50	100	200	400	800	1500
n	34	138	159	60	15	17
M _{RPG%}	0.84	0.56	0.57	0.53	0.75	0.32
SD _{RPG%}	1.26	1.13	1.01	1.27	1.32	1.33

DISCUSSION

General trend. The most unexpected outcome of this study is the fact of performance decline that embraces 68.2% of analyzed events. This fact was never marked in previous Olympics, and is inconsistent with findings of Pyne et al. (11), which reported average performance improvement in USA and Australian Olympic squads over the period between selection trials and Sydney Olympics, i.e. -0.2 and -0.6% respectively. It should be noticed that four world-leading teams (USA, Australia, Japan and Germany) in Athens earned 56% of 97 swimming Olympic medals (57.7%), however no one of them achieved average results’ progression for the entire swimming squad. Surprisingly these teams are coached by highly professional coaches and scientific experts, and enjoy high level conditions during the pre-Olympic preparation were the motivation and stimulation were extremely high. Hence, there were other factors affecting performance impairment in world-class competitors.

The selection mode, as a factor of peaking, has never been studied and analyzed previously. This doesn't mean that this factor was not in focus of sport experts. It was suggested, for instance, that earlier and more liberal selection provide the swimmers with a better psychological comfort and prevents emotional strain associated with the Olympic trials. The other experts, mainly from the countries, which enjoy large amount of high-level swimmers, believed that official Olympic trials are the only method for fair and reasonable selection. Present analysis revealed highly significant superiority of tough selection that can be explained by two reasons: (a) the athletes who passed stressful peaking stage before the Olympics within the same season received valuable experience that helped them in the ultimate phase of preparation, and (b) swimmers undergone a stressful tough selection developed efficacy beliefs, which enables them to tolerate more efficiently the emotional strain (16).

Athletic rank was found to strongly effect peaking. The analysis reveals that only winners and finalist swimmers improved their personal entry time, while the other swimmers failed to meet their personal best (see Figure 2). This is consistent with data of Trewin et al. (14), where swimming medalists in the Sydney Olympic Games obtained higher performance gains than other Olympians. Therefore, the outstanding Olympic achievements of the medal winners and finalists were substantially predisposed by their high improvement potential over the FSP. Review of genetic factors shows that the outstanding athletes are individuals, who inherited ability to respond better to training stimuli (2). Hence, the higher improvement rate over the FSP marked in successful Olympians attributed to both more favorable heredity and professional practices.

Duration of FSP. The study's findings don't give unequivocal position regarding the FSP duration. The marked tendency "the shorter – the better" is associated with outstanding performances of USA team, which practiced FSP lasted 29 days. However the majority of this leading squad (57.7%) failed to improve their entry times in the Olympic events. In addition, Canada National team used a similar FSP length (33 days), but was less successful than other world-leading squads (Figure 1). In light of recently published theory of Block Periodization (4, 5) the FSP should consist of three sequencing mesocycles, which total duration varies between 45-55 days, and this provides the optimal superposition of residual training effects. This length is also consistent with general positions of the theory of training (3, 10, 13). Nevertheless, the mentioned theoretical postulations were not confirmed by the present findings, thus requiring more studies of FSP duration and content.

Age and gender. The sport science analysts defined the optimal zones of top-performances in several sports; they pointed that these beneficial conditions for swimmers vary within 18-24 yr for men and 17-20 for women (9, 10). The present data don't confirm these positions – no significant benefits were found in any age category. Hypothetically, taking into account that female sex hormones activate other hormones (15), some gender effect could be expected and stress reaction of female swimmers can be different from the males. In fact no gender related difference was marked. It is likely that peaking problem is not gender dependent.

Swimming strokes and distances length were analyzed in view of the marked previously differences of metabolic responses in different strokes (6) and apparent physiological specificity of sprint, medium-, and long-distance training (17). These sup-

positions were not confirmed by statistical analysis; the similar performance decline was marked in different strokes and distances.

CONCLUSION

The results suggest that the marked tendency of performance decline during the Olympic competition was *not* determined by any of the common observable variables, such as FSP duration prior to the competition, age, gender, swimming strokes and distance. The probable reasons are rather associated with unobservable variables such as:

- (a) *Emotional strain and anxiety during the FSP and Olympic competitions*; factors such as the media, social commitments, expectations of sport administrators, anticipated bonuses, etc; all increase dramatically the incidence of emotional stress;
- (b) *Hormonal and metabolic changes induced by emotional and physical stress*; the emotional stress replaces physical stress a days prior the competition and this predisposes excessive catabolic responses; furthermore, increased catecholamines' excretion can reinforce anaerobic metabolism and modifies aerobic/anaerobic interaction;
- (c) *Training insufficiency during the FSP*; hormonal perturbations shift metabolic reactions into a direction of anaerobic prevalence and shortening of the aerobic and anabolic training residuals; this can follow to reduction of aerobic ability, muscle mass and power, which result in the marked tendency of performance decline.

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EVOLUTION OF BUTTERFLY TECHNIQUE WHEN RESISTED SWIMMING WITH PARACHUTE, USING DIFFERENT RESISTANCES

Fernando Llop¹, Victor Tella², Juan Carlos Colado³, Germán Díaz¹, Fernando Navarro¹

¹University of Castilla La Mancha, Spain

²University of Valencia, Spain

³University of Alicante, Spain.

The purpose of the study was to measure the effect on the stroke variables in speed (S), stroke rate (SR), stroke length (SL), and stroke index (SI) during swimming. Six tests were carried out. These tests consisted in swimming butterfly style 25 metres at maximum intensity using normal swimming (NS) and resisted swimming with parachute (RSWP) with a front span of 30cm and a back diameter of 30, 22.5, 15, 7.5 and 0cm. The study was carried out with 18 swimmers between 19 and 22 years of age. An intra-group design of repeated measures was used. The results obtained showed how the SF does not significantly vary with different diameter, but there are significant differences between NS and 0cm, 15cm and 30cm. Significant differences ($p < 0.000$), are produced in SL, S, SI between NS and all other diameter. This information will allow trainers to improve the mechanics of swimming butterfly style when performing RSWP.

Key Words: speed, stroke rate, stroke length, stroke index.

INTRODUCTION

The need to improve competition times encourages trainers to use different training methods. One of the methods used is sprint-resisted training. Sprint-resisted training aims at improving the strength of a swimmer by increasing the resistance a swimmer works against. The methods most used are resisted swimming with surgical tubing, the power rack and the parachute. Resisted swimming with parachute is a training method that allows the swimmer to have more mobility in the water compared to other methods. The possibility of modifying the back diameter of the parachute allows the trainer to adjust the force of the swimming and make modifications according to the needs of the swimmer. The problem with using resisted swimming with parachute is the difficulty of the trainer to measure the stress or resistance that the swimmer applies during training. Fully tethered swimming has been used as measured to record the propulsive force of the swimmer (10, 8, 13,

7). Some authors have observed that the use of these training methods of resisted swimming modifies the cinematic parameters (5, 3, 12). The trainer needs to know the exact changes that are produced during resisted swimming with parachute to be able to modify some aspects of training that may affect the speed and the technique of the swimming. The purpose of this study is to observe how the variables of speed (S), stroke rate (SR), stroke length (SL) and stroke index (SI) are modified when normal butterfly swimming is used and when the resisted butterfly swimming is used with parachute. The study also analyzes the change that is produced in resisted swimming with parachute when back diameters are changed to 30cm, 22.5cm, 15cm, 7.5cm and 0cm. The results obtained in the study will help trainers know what modifications are produced when the resisted butterfly swimming with parachute is used with the different posterior diameters. The trainers will be able to give their swimmers instructions about aspects that they must modify when this type of training is used and which period of the season is best for each type of training.

METHODS

Subjects

The study was carried out with 18 swimmers between 19 and 22 years of age 20.31 ± 1.65 years, size of 1.79 ± 0.06 cm, weight of 74.48 ± 6.53 kg and height of 1.82 ± 0.07 cm. Each swimmer completed 6 tests that consisted in swimming at maximum intensity 25 metres butterfly swimming using the normal swimming and 5 using resisted butterfly swimming with parachute.

Material

The parachute had a front diameter of 30cm and posterior diameters variable between 30cm and 0cm (Innosport, Parachute model 0190). The trials were performed in a 25meter indoor swimming pool. Vertical references were installed along the swimming pool lines to help measure the distance travelled during each trial. A video camera followed the swimmer's head and body in order to record displacement and to count strokes. From the video recording the average body speed, average stroke rate, stroke length and stroke index were obtained.

Variables

Dependent variables like swimming speed (MS) during distance, covered at each trial duration, average stroke rate (SR), average stroke length (SL) and stroke index (SI) were obtained or calculated and recorded. Six levels independent variables were defined: Normal butterfly swimming and resisted butterfly swimming with parachute of 30cm, 22.5cm, 15cm, 7.5cm and 0cm in back diameters.

Statistical Analysis

Average and standard deviations were calculated for each trial condition. An intra-group design of repeated measures was used. Analysis of variance of repeated measures was performed to find average differences between the independent variables. A P value of was regarded as significant.

RESULTS

In the analysis of the results in the variable of swimming speed it is observed that there are significant differences ($p < 0.001$) between the normal butterfly swimming and all the diameters

used in resisted butterfly swimming with parachute. There are also significant differences ($p < 0.001$) between the different diameters used except between the diameters of 0cm and 7.5cm and between the 7.5cm and 15cm where significant differences were not observed (Table 1) (Figure 1a). Significant differences are observed in stroke rate between normal butterfly swimming and the resisted butterfly swimming with parachute when the diameters of 0cm ($p = 0.015$), 15cm ($p = 0.001$) y 30cm ($p = 0.022$) are used, not having observed any in the diameters of 7.5cm y 22.5cm. Between the different diameters used during the resisted butterfly swimming no significant differences were observed (Table 1) (Figure 1b). In stroke length significant modifications are produced ($p < 0.000$) between normal butterfly swimming and all the diameters used in resisted butterfly swimming with parachute. They also found significant differences ($p < 0.05$) between all the diameters of the resisted butterfly swimming with parachute, except between the diameters of 0cm and 7.5cm and between 22,5cm y 30cm (Table 1) (Figure 1c). In the stroke index significant modifications are observed ($p < 0.000$) between normal butterfly swimming and all the diameters used on resisted butterfly swimming with parachute. Between the different diameters used on resisted butterfly swimming with parachute you could also observe significant variations ($p < 0.05$) except between 0cm and 7.5cm where no significant differences exist (Table 1) (Figure 1d).

Table 1. The descriptive statistics of speed, stroke rate, stroke length and stroke ind

Variables	N	Speed ($m s^{-1}$)		Stroke rate (Hz)		Stroke Length (m/c)		Stroke index ($m^2 s^{-1}$)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
0 cm	18	0,89	0,13	0,80	0,12	1,10	0,07	0,98	0,16
7.5 cm	18	0,90	0,16	0,81	0,14	1,11	0,10	1,01	0,22
15 cm	18	0,94	0,14	0,80	0,10	1,18	0,10	1,11	0,23
22.5 cm	18	1,03	0,15	0,81	0,13	1,28	0,12	1,33	0,25
30 cm	18	1,13	0,20	0,82	0,11	1,36	0,12	1,55	0,37
Normal	18	1,48	0,17	0,87	0,11	1,71	0,14	2,53	0,40

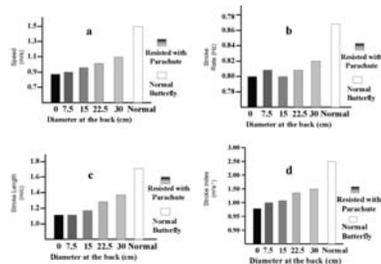


Figure 1. Differences in speed, stroke rate, stroke length and stroke index between normal butterfly and resisted swimming with parachute with a back diameter of 30, 22.5, 15, 7.5 and 0cm.

DISCUSSION

The purpose of this study was to add to the current knowledge of the effects of resisted swimming on butterfly stroke mechanics. The results indicate that there are important modifications in the variables when you compare normal butterfly swimming with resisted butterfly swimming with parachute and the different diameters used. When the resisted butterfly swimming with parachute is used, there is a decrease in the different parameters,

between 39,86% and 23,64% in the speed (S), between 8,04% and 5,74% in the stroke rate (SR), between 35,30% and 20% in the stroke length (SL) and between 61,26% and 39,13% in the stroke index (SI). Resisted swimming caused a significant decrease in speed, stroke rate, stroke length, and stroke index. This suggests a negative effect on stroke mechanics; ideally swimmers are encouraged to increase stroke length while maintaining stroke rate (6). The present results are consistent with the findings of (11, 12, 3) in that resisted swimming produced a decrease in both stroke rate and stroke length with no significant change in stroke depth when compared to free swimming. As the parachute's back diameter decreases the swimmer must use higher values of contractile muscular force which and reduces his speed and decreases stroke length significantly. It may be possible to think that the changes are induced in the muscle level at a higher value than in the stroke mechanics level because more force is needed to move the hand through the water as (1, 2) concluded in their studies. There appears to be a large number of undesirable changes made to stroke mechanics during resisted swimming butterfly, which makes this form of training questionable. Trainers must consider resisted training with parachute a beneficial way to work muscle power specifically in water. They should keep in mind that the use of different parachute diameters should be progressive permitting swimmers to adapt to the mechanics of training resisted swimming. Trainers should show swimmers the adequate swimming mechanics when using resisted swimming with parachute, not permitting an important decrease in stroke length. Training with parachute should be used with large diameters when a competition is near in order to reduce its negative effects on speed.

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SWIMMING VELOCITY IMPROVED BY SPECIFIC RESISTANCE TRAINING IN AGE-GROUP SWIMMERS

Georgios Mavridis, Christos Kabitsis, Vassilios Gourgoulis, Argyris Toubekis

Department of Physical Education and Sport Sciences, Democritus University of Thrace, Komotini, Greece.

The purpose of the study was to examine the influence of a 12-week sprint-resisted training period on 10m sprint swimming time (T10) and competitive performance (P). Eighty-two (n=82) swimmers were assigned to an experimental (E, n=53) and control (C, n=29) group and followed three sprint training sessions per week, with and without resistance respectively. Resistance was applied by a bowl tethered with an elastic rope to the hip of the swimmer. Post-training T10 was improved compared to pre-training ($p<0.05$). Group E displayed significant T10 improvement compared to group C ($8.5\pm 4.1\%$ vs. $1.2\pm 1.6\%$, $p<0.05$). Percent improvement of P on distances of 50-100-200m was higher in group E compared to C ($p<0.05$). The applied form of sprint-resisted training method is recommended for development of speed and may also be effective for competitive improvement.

Key Words: sprint training, resistance, performance.

INTRODUCTION

Strength is one of several important components of swimming performance and should be developed during a training season (2). However, the strength developed out of the water fails to replicate the three-dimensional pattern of swimming movements (7) and may not be transferred on effective propulsive movements at specific velocities to improve swimming speed (8). Several specific forms of resistance training have been applied to improve swimming velocity (1, 3, 6, 9) and sprint-resisted training is suggested for swimming performance improvement (5). Resistance on swimming propulsion in the water may also be caused by having the swimmer carrying a light load tethered behind him (4). However, the effectiveness of this method has not been examined. The purpose of the study was to examine the influence of a 12-week sprint-resisted training period on maximum swimming velocity and competitive performance.

METHODS

Eighty-two (N=82) swimmers were assigned to an experimental (E, n=53, age 14.7 ± 1.5 yrs) and control (C, n=29, age 15.0 ± 1.5 yrs) group, balanced for sex, swimming style and

competitive performance. Both groups (E and C), followed three sprint training sessions per week, with and without added resistance respectively, in addition to their daily training. Added resistance was applied by a bowl (35cm diameter, with an additional load of 170gr and 5 holes of 8mm diameter) tethered by its convex side with a rope attached to the hip of the swimmer. During a 12-week period and three times per week all swimmers performed a set of 2x50m at intensity 70% and 4x25m exerting maximum effort using their personal style and starting every 1min and 45s. The set was repeated three times during each session. Swimmers of the E group performed the repetitions of the set with the added resistance described above. Swimming time during a 10m test, performed with added (RT10) and without resistance (T10) was evaluated before and after the training period using two pairs of photocells (Lafayette instrument Model 635011R). The photocells were adapted, 30 cm above the water surface and at a distance of 2 m between them, on tripods fixed to the bottom of the swimming pool. A snorkel worn on the head of the swimmer was used to activate the photocells. Swimmers were tested using their individual best swimming stroke. Initial swimming time on distances of 50-100-200m was considered the record achieved during the summer championship of the previous season and compared to the swimming time recorded during competition of the winter season. Analysis of variance for repeated measures and a student t-test (for % differences) were applied for the statistical analysis and the Tukey post-hoc test was used for multiple comparisons. The results presented as mean \pm SD and the accepted level of significance was set at $p<0.05$.

RESULTS

At the end of the 12-week training period swimmers improved the RT10 and T10 compared to pre-training (fig. 1, $p<0.05$). However, the improvement was significant only for swimmers of group E (fig. 1). In this group, after the training period, swimmers were faster for the T10 by $8.5\pm 4.1\%$ compared with only $1.2\pm 1.6\%$ improvement of the swimmers of group C (between groups, $p<0.05$). The RT10 was also improved significantly after training for group E only ($p<0.05$) and the percent improvement was greater compared to group C (E: $5.9\pm 2.9\%$ vs. C: $1.2\pm 1.6\%$, $p<0.05$). Similar improvements were observed when the T10 and RT10 were examined for each swimming style separately (table 1).

Table 1. Swimming time for T10 in different styles.

Swimming time for each style (s)									
Group	Butterfly		Backstroke		Breaststroke		Frontcrawl		
	pre	post	pre	post	pre	post	pre	post	
E	7.49 (0.62)	6.90* (0.54)	7.48 (0.76)	6.89* (0.68)	8.45 (0.89)	7.80* (0.82)	6.71 (0.40)	6.18*	(0.34)
C	7.32 (0.62)	7.17 (0.51)	7.68 (0.76)	7.60 (0.70)	8.91 (0.88)	8.88 (0.84)	6.83 (0.47)	6.76	(0.33)

E: experimental group, C: control group, * $p < 0.05$ pre vs. post-training

Competition time for 50m was significantly improved in both groups ($p < 0.05$, table 2). Group E improved by $3.6 \pm 2.2\%$ compared to $1.9 \pm 2.4\%$ of group C ($p < 0.05$, fig 2). The competition time for 100 and 200m distances was improved in group E only ($p < 0.05$, table 2) and the percent improvement was higher in group E compared to C ($p < 0.05$, fig 2).

Table 2. Competition times for 50, 100, 200m before and after the training period.

Swimming time for each competitive distance (s)						
Group	50m		100m		200m	
	pre	post	pre	post	pre	post
E	33.74 (3.85)	32.55* (3.49)	73.13 (8.66)	70.83* (7.86)	159.59 (18.34)	154.5* (17.39)
C	33.63 (3.87)	32.97* (3.55)	72.91 (8.71)	71.83 (7.85)	159.19 (18.34)	157.66 (17.43)

E: experimental group, C: control group, * $p < 0.05$ pre vs. post-training.

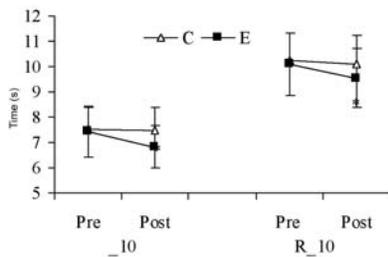


Figure 1. Swimming times during the 10-m sprint test with (RT10) and without added resistance (T10). * $p < 0.05$ compared to pre-training.

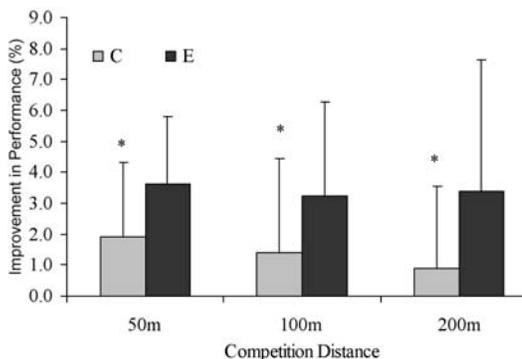


Figure 2. Percent improvement in competition swimming time after the training period. * $p < 0.05$ between groups.

DISCUSSION

The application of this mode of sprint-resisted training using a bowl tethered behind the swimmer was superior compared to free swimming training for the improvement of the time to swim 10m. Additionally, this type of resistance training improved the competition time more compared to the normal swimming training.

Improvement on sprint swimming times, when a specific resistance swimming training is used, has been reported previously (1, 3, 9). The increased swimming velocity may be attributed to increased stroke length (SL), stroke frequency (SF) or both. Some gain on specific swimming strength is also a contributing factor to improvement. In the present study the technical parameters (SL and SF) and swimming forces were not measured. However, according to Toussaint and Vervoorn (9) swimming force was marginally improved but number of strokes was reduced and probably this is attributed to increased power production. In the present study the swimmers of the E group also improved the 10m time swimming with the added resistance (RT10). Since the load applied to the swimmers was exactly the same before and after the 12-week training period, but velocity to carry it was higher, it is possible that this occurred with improvement in swimming power. Competitive performance was improved more in the E compared to C group. Swimmers of the C group improved only in the 50m but not in 100 or 200m. Improvement in performance of the E group could be attributed to increased power output during swimming (2) and this probably occurred in our study if we consider the increased velocity during the RT10 test. It should be noted that swimmers followed different swimming training sessions since they trained on different swimming clubs. Therefore, training history before the 12-week period was different and may have affected the competition performance. Other factors such as taper may also have influenced performance. Furthermore, the change on performance of the E group was similar to the expected from year to year improvement in swimmers of this age-group (5). A more controlled examination is needed to establish a clear competitive performance gain with this type of resistance training.

CONCLUSION

The applied form of sprint-resisted training method had a positive outcome in developing speed on all four competitive strokes. Thus, it is recommended for development of maximum swimming speed. Further research is needed to examine the effect of this type of training on performance during competition.

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ANALYSIS AND COMPARISON OF RESULTS OF THE MADER TEST IN DIFFERENT STROKES IN AGONISTIC SWIMMERS

Michielon G, Invernizzi PL, Scurati R, Pizzini G

Laboratory of Sports Analysis, Faculty of Exercise Sciences, University of Milan, Italy.

Several studies were performed to analyze both the blood lactate concentration after competitions and to set the optimal intensity level during the training. The aim of this study was to evaluate the differences in lactate production between high level male and female four-strokes-swimmers and the differences in lactate concentrations among these strokes in swimmers of the same gender. Forty male and forty female swimmers performed a modified Mader test in their own discipline. The time for 200m at the threshold speed, the [La⁻] peak and the [La⁻]/time at the anaerobic threshold ratio were considered. Male athletes produced more lactate for each stroke than the female counterparts. The higher peak lactate concentration in the male athletes were found in breaststroke, whereas in females athletes the higher peak was found in butterfly.

Key Words: swimming evaluation, blood lactate, Mader test.

INTRODUCTION

In literature several studies appears on the analysis both of the blood lactate concentration after competitions and of the optimal intensity level set up, during the training. These studies can be classified into the following categories: (i) those who tried to found justifications for the use of Mader test such as an useful tool of monitoring training effects on aerobic and anaerobic systems (4, 7, 8); (ii) those who tested the modification of the Mader test in distance and trials number (5, 8, 10); (iii) the ones that analyse and compare the swimming velocity at the anaerobic threshold in athletes of different levels (10); (iv) those who analyse the improvements after specific periods of training (10); (v) the ones that compare the concentrations of lactate in athletes of different strokes and gender at the end of competitions (1, 3, 12) and, finally, (vi) those who try the comparison of different tests to set the anaerobic threshold (9). The original Mader's protocol is often used to find the speed

that corresponds to the anaerobic threshold; this consists in two separate trials of 400m swimming at a constant speed: the first one at about 85% maximal speed, the second at maximal speed (2, 7). In this study, we used the modified Mader test that provides trials of 200m instead of 400m (2).

The aim of this study was to evaluate the differences in lactate concentrations between high level male and female four-strokes-swimmers, and the differences in lactate concentrations among these strokes in swimmers of the same gender.

METHODS

We studied 40 high level males swimmers (age 17.3±0.2, height cm 179.1±4.7, weight kg 74.0±1.7, BMI 22.0±1.2) and 40 high level females swimmers (age 16.0±0.2, height cm 163.8±3.3, weight kg 54.1±2.5, BMI 20.4±0.8). Athletes were divided into four male groups and four female groups of 10 subjects each.

The groups performed the modified Mader test in their own discipline (crawl, butterfly, backstroke, and breaststroke), with a rest period of 20 minutes between the first and the second trial. First trial was performed at sub-maximal speed, where the lactate concentration did not exceed over 4 mmol/l, while second trial was performed at maximal speed. The request to perform the test at a pace corresponding to a lactate concentration near or under a 4 mmol/l is due to the fact that, according to the literature (8), a fixed blood lactate concentration of 4 mmol/l overestimates the anaerobic threshold speed.

The tests were performed in a 25m indoor swimming pool using in-water starts (without diving). A fingertip sample of capillary blood was collected three minutes after the end of each trial. Blood [La⁻] were assessed using a "Lactate Pro" auto-analyser.

The swimming velocity corresponding to the anaerobic threshold was calculated mathematically. This velocity results from the equation $y=mx+q$, obtained from the data collected in the two speed test. We conducted a comparison of the *time for 200m at the threshold speed*, of the *[La⁻]/time at the anaerobic threshold ratio* and of the *[La⁻] peak* (peak lactate concentration) between groups of the same stroke and different gender. Moreover, we compared the values among groups of the same gender.

These comparisons were carried out using the Student's *t* test for $p<0.05$.

RESULTS

The values of *time for 200m at the threshold speed* showed significant differences between male and female swimmers for crawl, butterfly and breaststroke (table 1).

The values of *[La⁻] peak* showed significant differences on four strokes between males and females. The *[La⁻] peak* was within 9 – 11 mmol/l

Table 1. Gender comparison of 200m event time at threshold speed and [La] peak per swimming stroke group, and ratio [La] peak / 200m time at threshold speed ($\text{mmol}^{-1}\cdot\text{s}^{-1}$). (Mean \pm SD). In bold the higher [La] peak mean value found for each gender in each stroke.

	Time at threshold speed (s)		[La] peak (mmol^{-1})		[La]/time anaerobic threshold				
	Male	Female	Male	Female	Male	Female			
Free	145.72 \pm 13.97	139.12 \pm 8.02	**	11.00 \pm 1.59	9.34 \pm 1.91	*	0.0275 \pm 0.002	0.0251 \pm 0.001	**
Fly	171.93 \pm 10.19	176.70 \pm 5.85	**	11.24 \pm 1.30	10.17\pm1.46	**	0.0233 \pm 0.001	0.0223 \pm 0.007	*
Back	166.36 \pm 14.24	171.80 \pm 14.14		11.35 \pm 2.36	8.96 \pm 1.74	**	0.0241 \pm 0.002	0.0233 \pm 0.002	
Bre	180.32 \pm 7.61	198.16 \pm 9.71	***	11.93\pm1.15	9.01 \pm 1.76	**	0.0241 \pm 0.009	0.0202 \pm 0.001	***

Significant differences are shown: * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

DISCUSSION

According to Bonifazi (1) and Chatard (3), male athletes produce more lactate for each stroke than their female counterparts. Some authors explain this phenomenon with a lower muscular mass/blood volume ratio in female subjects (11), other authors state that they produce less lactate and eliminate it faster than male subjects because of a lower glycolytic activity of musculoskeletal system, associated with a higher capacity of lactate oxidation (6). However, it is not possible to exclude that the differences found could depend on the fact that, on average, females athletes practice less than the males (1). Telford and coll. (12) did not found any difference on lactate concentration after race between male and female swimmers. For male athletes we found the higher peak lactate concentration in breaststroke, according to Chatard (3), whereas in females athletes the higher peak was found in butterfly, not in backstroke, as it was found by Chatard (3).

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A THREE-YEAR FOLLOW-UP STUDY OF AGE GROUP SWIMMERS: ANTHROPOMETRIC, FLEXIBILITY AND COUNTER-MOVEMENT JUMP FORCE RECORDINGS

Esther Morales, Raúl Arellano

Faculty of Physical Activity and Sport Science, University of Granada, Spain.

The purpose of this study was to investigate the changes brought about both by this development and by training on anthropometrics, swimming, flexibility and CMJ force recordings variables over a period of three years (2000-2003) of swimming training in a sample of age-group swimmers. The improvement obtained in swimming times seems related to a combination of anthropometrics factors plus absolute and relative force development after ending this long-term period of swimming age-group training, but the growing changes seems to produce a masking effect on the force evolution observing the relative force results. Considering that we evaluated the general jumping force, not strictly related with the swimming needs, it is difficult to recommend, to this group of age-group swimmers, the application of a rigid and progressive strength-training program.

Key Words: growth, pubertal, development, swimming training.

INTRODUCTION

Young swimmers training and performance can be affected by many factors, but it seems that the most relevant are induced by the growth, development and maturation of pre-pubertal and pubertal periods (2). With normal development, the greatest structural change in the motor skills occurs at the ages of 10 to 11 and 15 to 16. At these ages there is also a change in the athletic movements (5). Prepubertal subjects, both boys and girls, do demonstrate improvements in strength with resistance training that are quantitatively similar to those of older subjects (3). But the typical training programs developed in swimming did not include a specific work related with muscular force in these ages. The expected changes in growth and developments are considered sufficient to accompanying the volume and technical work evolution of training program and therefore improve the performances continuously. This seems logical when the reported data from young development experts show an increase of the muscular force (hand-grip) about three times in male and two times in female from ten to eighteen years without specific training (3). But the question

remains unsolved. Is the absolute and natural strength development enough to improve the performance in all type of swimmers? The situation is more complex when other qualities as flexibility (thought important in swimming) do not improve in the same path during this maturation period furthermore it does not improve at all (2) without specific and enough training. Physical growing determines more relevance to performance than other factors when the water active drag is considered as studies applying the MAD system confirmed. The body size improvement did not increase active drag, kept constant during the pubertal development period (4). The purpose of this study was to investigate the changes brought about both by this development and by training on anthropometrics, swimming, flexibility and CMJ force recordings variables over a period of three years (2000-2003) of swimming training in a sample of age-group swimmers.

METHODS

Subjects: Twenty-one swimmers (female=12 and male=9) participated in the study (average age at beginning = 12, 19 years). They were included in a regular training program for national and state level swimmers. The ages of the subjects group are specified in the table 1.

Instrumental: Body measurement instruments were applied to measure all the anthropometric characteristics. A standard force plate was used to measure the legs impulse variables during a counter movement vertical jump (DinaScan/IBV600M). Flexibility measurements were performed using videography (see Figure 1) plus a specific software able to measure angles after digitising body landmarks (1). The swimming times were collected from competition results (first measurement, year 2000) and from training testing in the second assessment (year 2003). These changes in the testing environment could mask greater improvements.

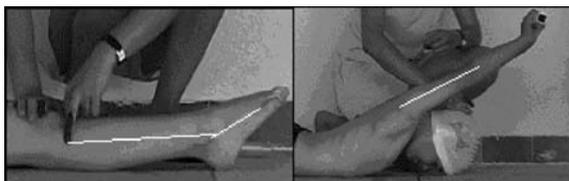


Figure 1: Measurement of ankle and shoulder flexibility using videography.

Variables. Independent variable: The different levels of training loads performed by the subjects during the three years of training and data collection combined with the physical growth.

Dependent variables: The anthropometric variables considered were height (cm), weight (kg) and arm spam (cm). The flexibility measures were ankle flexion (°) and shoulder hyper-flexion (°, related to the horizontal line). The analysis of counter movement jump (CMJ), resulted in the following data: peak vertical force (N), peak vertical force related to body-weight in N, height of the jump (m) and maximum vertical velocity (m/s). The 50m freestyle time (s) was collected using an official electronic timing system.

Statistics. SPSS 12.1 was used for statistic analyses. Descriptive data were obtained and showed as mean and standard deviation (SD). Homogeneity and normality of data were analyzed

before applying the T-test to related samples. Pearson product moment correlation was calculated among variables. The interval of confidence accepted for all comparisons was less than 0.05.

RESULTS

The results are shown in table 1. Weight, height, and arm spam showed a significant increase (21%, 4% and 4%) respectively. The different found in weight related to height and arm spam denotes an evolution not expected after this period of formal training (about two hours five or six times every week). The flexibility variables denoted a decrease of motion range, specially the ankle flexion where the difference is significant. The peak vertical force increased a significant 14%, while the peak vertical force related body-weight showed a non-significant decrease. This data is in agreement with the previously reported and unexpected increase of body weight. The peak vertical force improvement obtained is related to the body weight. This is explained by the results of height of jump that were not significantly changed (with slight reduction). The take-off vertical velocity showed a similar trend. A significant improvement (4%) of average 50m time was recorded.

Table 1. Mean and standard deviation (SD) of the variables studied. The significant changes are marked with asterisks.

	2000		2003	
	Average	S.D.	Average	S.D.
Weight (kg)	50,01	9,64	60,71**	10,12
Height (cm)	160,07	8,17	166,90**	6,02
Arm Spam (cm)	163,09	9,56	170,75**	7,88
Shoulder Flex. (°)	167,90	5,22	163,68*	7,70
Ankle Flex. (°)	10,57	11,73	9,00	26,04
Max. Force (N)	1233,73	271,47	1415,78**	238,07
Relative Force (N)	2,50	0,19	2,42	0,25
Height of jump (cm)	29,67	0,64	31,33	0,78
Take-off vel. (m/s)	2,40	0,25	2,46	0,28
50 m swim freestyle	31,32	1,90	30,29**	1,98

*p<0.05; **p<0.01

Low and very low coefficients of correlation (not significant) resulted after performing a correlation matrix between all the variables obtained at 2000 year. Similar results were obtained at 2003. Only the vertical take-off velocity showed a high and significant correlation (r=0.99, p<0.01) with height of jump. Similar results were found between all the anthropometric variables studied and among these variables and peak vertical force. The 50m times obtained a medium and significant correlation's coefficient with arm spam (r=-0.62, p<0.01), peak vertical force (r=-0.72, p<0.01) and relative force (r=-0.56, p<0.01) at the second test (after three years).

DISCUSSION

As was to be expected, the subjects after this period had increased weight, height and arm span due to the growth process. Flexibility has very specific characteristics and slowly diminishes with age, a diminution that is accelerated if it is not worked at. These data verify previous findings (2), they argued that at the beginning of the pubertal period the amplitude of movements diminishes significantly. For this reason most

authors suggested that the training of this quality should be intensified at the end of the pre-pubertal period. Our results confirm the process of the evolution of force (3). The subjects in this group obtained significant improvement in maximum force probably due to their growth and development, while the relative force and height of jump did not change. This result is caused by unfavourable improvement of the body-weight a 21%, higher than expected in a group of young sport practitioners. The improvement obtained in swimming times seems related to a combination of anthropometrics factors plus absolute and relative force development after ending this long-term period of swimming age-group training, but the growing changes seems to produce a masking effect on the force evolution observing the relative force results. Considering that we evaluated the general jumping force, not strictly related with the swimming needs, it is difficult to recommend, to this group of age-group swimmers, the application of a rigid and progressive strength-training program. It seems more logical, to recommend a simple diet control routine to avoid the excessive body-weight development observed in this group of swimmers, combined with a progressive increase of the training loads. This control will increase the value of the relative force.

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EFFECT OF TEACHING POINTS ON TURN MOTION OF BREAST-STROKE FOR BEGINNING-SWIMMERS

Ohba M, Takahashi M, Shimoyama Y, Nomura T
Niigata University, Niigata, Japan.

The purpose of this study is to evaluate the effect of teaching points on turn motion by investigating the relationship between subjective sense and objective temporal information during breaststroke turn motions for novice swimmers. Eight non-skilled college swimmers participated in this study. They were taught the turn motion three times for 15 min. The times for T-turn (Pre, 1.71 s; Post, 1.84 s) and T-hand (Pre, 0.65 s; Post, 0.86 s) were significantly longer ($P < 0.01$) than those before teaching. Many positive comments were offered, such as "I learned to be able to turn my body with no trouble" and "I was able to kick the wall firmly", implying that these teaching points eased turning for beginning swimmers. Results suggest that the teaching program led swimmers to acquire good tips on turn motion and led them to turn confidently.

Key Words: breaststroke turn, teaching, turning coordination, beginning swimmers.

INTRODUCTION

Breaststroke turns require a simultaneous two-hand touch at the wall, followed by body rotation and pushing off into the next swim. For competitive swimmers, the body must change direction in the shortest possible time, and the legs must extend powerfully when pushing off the wall, thereby achieving the highest possible speed in the opposite direction. Tourny-Chollet et al. (4) showed that, for the butterfly-stroke turn, longer contact times of feet on the wall were associated with a faster push-off speed. Huellhorst et al. (2) showed similarities in the displacement curves of the centre of gravity in spite of individual differences.

On the other hand, novice swimmers must have a stable turn motion for leading into the next swim. They experienced difficulties in performing breaststroke turns in a smooth and easy motion because of its complexity. For those reasons, specific skills are required in order to produce an efficient turn motion. Few studies have been conducted on the turning motion for beginners. Guzman (1) showed a turning description and focus points, in "Swimming Drills for Every Stroke".

Using investigation of the relationship between subjective sense and objective temporal information, this study was intended to evaluate the effects of teaching points on turn motion during novice swimmers' breaststroke turn motion.

METHODS

Experimental design

Eight non-skilled college swimmers participated in this study. They were taught the turn motion three times for 15 min. Turn trials were conducted to analyse the turn motion before and after teaching (fig. 1). Before free practice, an example of a competitive swimmer's demonstration was shown. Pre-test (Pre) trials were conducted after the practice. The first lecture's point showed how to touch the wall, from the fingertips to the palm. The second lecture's point was the direction of the eyes during body rotation. The third lecture's point explained how to push off the wall.

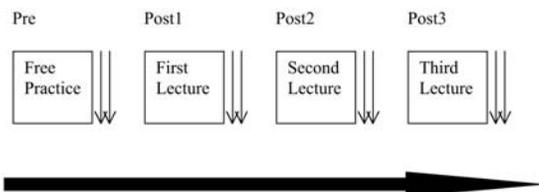


Figure 1. Experimental design.

Measurement methods

Each test was recorded using two digital video cameras for motion analysis, and another camera for measuring the overall turning time (T-turn – the time from touching with hands to pushing off with the feet) and the hand contact times (T-hand – the time from touching with hands to releasing).

Teaching points

The breaststroke turn was separated into three phases: (i) the approach, (ii) turning the body, and (iii) push-off. The turning phase is divisible into three sub-phases: (i) the hand contact phase, (ii) the rotation phase, and (iii) the foot contact phase. Respective contents and focus points of teaching were: (i) how

to touch at the wall from fingertips to palm, (ii) direction of the eyes during body turning, and (iii) how to push off the wall.

First, a training menu for “how to touch” was followed: the hand falls toward the wall; the hands support the body, then the body pushes off. Second, the menu for rotation was to stop turning during touching with the feet. The third was pushing off to the side.

Questionnaire survey

Questionnaires on subjective sensations of the turn motion were completed after the test. These teaching points were evaluated by swimmers for their effectiveness from three points (rapidly, correctly and easily) using a five stage standard (see the caption of fig. 2). In addition, the swimmers freely described changes in the turning motion.

RESULTS

Turning time changes

Table 1 shows the turning times before and after instruction. The T-hand times (Post1, 0.83 s; Post2, 0.95 s; Post3, 0.86 s) were significantly longer ($p < 0.01$) than those before teaching. The T-turn times (Post1, 1.68) were not longer after the first lecture, in spite of longer hand contact. The T-turn times (Post2, 1.86 s; Post3, 1.84 s) were significantly longer ($p < 0.01$) than those before instruction. It seemed that other times, aside from those of T-hand (Pre, 1.06 s; Post1, 0.85; Post2, 0.91; Post3, 0.98 s), were shorter before teaching. Results showed that the ratio of T-hand/T-turn times changed greatly.

Table1. Turning Time before and after teaching

	Pre	Post1	Post2	Post3
T-hand(sec)	0.65	0.83 **	0.95 **	0.86 **
T-turn(sec)	1.71	1.68	1.86 **	1.84 **
T-hand/T-turn	37.9%	49.1%	51.4%	46.8%

** $p < 0.01$

Questionnaire survey results

Figure 2 shows responses to the question of whether the lecture was effective. All subjects felt that the present teaching was effective in improving their turn motion in spite of a short teaching program. Particularly, it was effective to turn easily. Point2 tended to be higher than either point1 or point3. Many positive and a few negative comments were received. After the first lecture, exemplary comments were “I learned to have no trouble turning my body” and “I was not able to kick the wall firmly because my body left the wall.” After the second lecture, positive comments such as “my body did not leave the wall and it is now possible to strongly push off of it” and “I was able to push off straight and kick the wall firmly” were most common. After the third lecture, some negative comments were received, such as “I was not able to push off straight” and “Because I kept thinking about what I was doing, I became confused.”

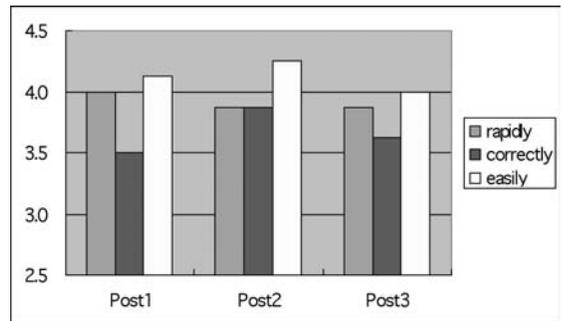


Figure 2. Questionnaire results (Was it effective?). 5: Very; 4: Probably; 3: I can't really say either way; 2: Probably not; 1: Definitely not.

DISCUSSION

After the first lecture, the hand contact time (T-hand) lengthened significantly. The associated major comments were: “I learned to be able to have no trouble turning my body.” The subsequent rotation movement was inferred to become smooth because the swimmer came to get support from the wall by hand contact. On the other hand, comments such as “I was not able to kick the wall firmly because my body left the wall” also existed, suggesting that it was difficult for beginners to push moderately.

Very positive comments were received after the second lecture. The T-hand and T-turn times lengthened significantly. Especially, the instruction was effective to ease swimmers’ turning. Point 2 tended to be higher than either point1 or point3. Apparently, it was very important to maintain the head position at the beginning of the rotation phase. The second lecture was very effective for stable turning of beginning swimmers. On the other hand, some negative comments were received after the third lecture. It is apparently extremely difficult for novice swimmers to push off on their side. Results show that the ratio of T-hand/T-turn times changed greatly before and after instruction. In a study of competitive swimmers (3), the ratio of T-hand/T-turn was about 45%. Although the turning time is much longer than that of competitive swimmers, the ratio after instruction closely approximates that of competitive swimmers (46.8%). Results suggest that a moderate balance exists for breaststroke turning and that such balance is necessary for swimmers. I decided to name that balance “turning coordination”.

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TRAINING INDUCED CHANGES IN CRITICAL VELOCITY AND V4 IN AGE GROUP SWIMMERS

Joana Reis, Francisco Alves

Faculdade de Motricidade Humana, Lisboa, Portugal.

The aim of this study is to determine the relationships between different methods of assessing aerobic capacity and the changes induced by a heavy aerobic training period in age group swimmers. It was found that critical velocity in front crawl, determined using 50, 200 and 400 meters distances, is similar to velocity correspondent to lactate concentration of 4 mmol.l⁻¹. Critical velocity determined using just 200 and 400 meters distances, however, was significantly different from the former but similar to the mean velocity of the 2000m test. All variables increased significantly after a 9 weeks aerobic training phase, simultaneously with best performance at 400m front crawl. The results of this study confirm that critical velocity is sensitive to performance changes induced by aerobic training in young swimmers.

Key Words: critical velocity, training, age group swimmers.

INTRODUCTION

The effectiveness of the demanding training processes to which swimmers are frequently exposed must be periodically verified. Several parameters have been used in the last decades for this effect, most of them using the determination of lactate concentrations in protocol progressive testing situations. The invasive nature of these procedures raised the need for alternatives, especially in what regards age group swimmers.

The slope of the regression of total work performed against the corresponding time to exhaustion, the critical power was thought to correspond to the intensity above which no oxygen uptake steady state is possible (11). The velocity asymptote of the hyperbolic relationship between velocity and time to exhaustion, or by conversion the slope of the linear relationship between distance and time to exhaustion, usually termed critical velocity (Vcri), has the same physiological meaning than critical power. In theory, the maximal lactate steady state (MLSS), which is the highest work rate that can be maintained over time without continual blood lactate accumulation (2), is the same as the concept of critical velocity.

In swimmers, Vcri has been shown to be highly correlated with the oxygen uptake at the anaerobic threshold, the swimming velocity at a fixed blood lactate concentration of 4 mmol.l⁻¹ (V4), the MLSS and race velocities of 200- and 400-m front crawl (13, 15, 16) suggesting that it could be adopted as an index of endurance performance, contrarily to what has been found regarding the interpretation of y-intercept as a marker of anaerobic work capacity, within the 2-parameter model (14). However, several studies indicated that Vcri overestimates MLSS velocity (3, 10), contesting its validity for training prescription. Studies with young swimmers have not produced consensual results as well, revealing Vcri to be lower (5, 6, 13) or similar (7, 13) to V4, depending on the duration and the number of trials used for its calculation.

However, mean velocity in long duration constant intensity swim exercises, as the 30 min duration exercise or in distances of 2000 or 3000 m, providing another indirect estimation of MLSS velocity (12), has been found to match Vcri very closely (4, 6, 8).

Furthermore, the sensitivity of critical velocity to training adaptations in the course of the competitive season has not yet been verified for age group swimmers.

The aims of this study were 1) to verify the relationships established between non-invasive methods of monitoring training, critical velocity and mean velocity obtained in a 2000 meters trial in front crawl and V4 and 2) to assess the training induced changes in these parameters in age group swimmers.

METHODS

Twenty nine national level age group swimmers, 18 males and 11 female (age = 12.9 ± 1.15 years, weight = 54 kg ± 10.7, height = 165.7 cm ± 9.4) participated in this study, after giving written consent.

Each subject was tested in the beginning of the general preparation period (1st stage) and after nine weeks of a predominantly aerobic training phase, incorporating a volume of 20–40 km/week (2nd stage). Testing procedures took place in a 25 m indoor swimming pool and at the same time of the day to minimize circadian influences. In the first day, the subjects were asked to swim 2 trials at maximal velocity: 50 and 400 meters front crawl, after a warm-up of 1000 meters and with 40 minutes rest between the trials. After 24 hours, each subject executed a 2000 meters trial at maximum but constant intensity for determination of mean swim velocity (V2000). Blood was sampled after one minute and lactate concentration was determined (La2000). In the third day, subjects performed two repetitions of 200 meters freestyle, one at 85% and another at maximal speed with 40 minutes rest, for determination of V4 (12). Mean velocity obtained at the 200m maximal trial was integrated in Vcri calculations. Vcri was calculated from the slope of the regression analysis between the distances performed and the correspondent time (15). Vcri1 was estimated from 50, 200 and 400 meters trials, and Vcri2 only from 200 and 400 meters trials.

Paired-samples t-test was used to compare intra and inter-stage mean values for each variable. Pearson's linear coefficient was used to test correlations. Statistical significance was accepted at p<0.05.

RESULTS

The mean velocities measured in 400 e 2000 meters trials, jointly with the Vcri1, Vcri2 and V4 calculated in each testing stage are exposed in table 1. Table 2 shows the correlation coefficients among the performance variables. All the Vcri individual linear estimates had r² values greater than 0.99 (p<0.01).

Table 1. V50, V200, V400, Vcri1, Vcri2, V4, V2000 and La2000 values in the two testing stages.

	V400 (m.s ⁻¹)	Vcri1 (m.s ⁻¹)	Vcri2 (m.s ⁻¹)	V4 (m.s ⁻¹)	V2000 (m.s ⁻¹)	La 2000 mmol.l ⁻¹
1 st stage	1.17±0.1	1.12±0.10	1.08±0.11	1.11±0.086	1.07±0.096	5.75±2.3
2 nd stage	1.23±0.1	1.20±0.11	1.14±0.08	1.19±0.09	1.13±0.09	4.5±1.7

In each stage, Vcri1 was not significantly different from OBLA velocity, but was significantly higher than V2000 and Vcri2. Although all the inter-stages differences were statistically significant, the increase of the variables was not identical. In fact, V400 (4.2%±2.2), Vcri1 (4.8%±2.5), Vcri2 (5.2%±2.7) and V4 (6.6%±2.1) showed remarkably higher increases than V2000 (1.6%±1.4). Vcri1 and Vcri2 corresponded to 96.4% (1st stage) and 96.8% (2nd stage) and to 92.9% and 94.5% of V400, respectively.

Table 2. Correlation matrix for variables measured in 1st stage/2nd stage.

	V400	Vcri1	Vcri2	V4
Vcri1	0.996/0.998			
Vcri2	0.934/0.965	0.957/0.969		
V4	0.931/0.95	0.937/0.943	0.914/0.880	
V2000	0.891/0.917	0.900/0.921	0.891/0.856	0.903/0.880

DISCUSSION

As expected, V4, V2000, Vcri1 and Vcri2 were highly correlated. However, Vcri1 and Vcri2 were significantly different. Distance used for the determination of Vcri interfered on its value, irrespective of the evaluation stage. The inclusion of a shorter distance, the 50m, with duration ranging from 28.2 to 32.35 sec increased the estimate of Vcri by 5.5%, in average. As noted before (4), lower duration times to exhaustion produced higher slopes. The use of such short duration exercise bouts for the calculation of Vcri, in the context of the two-parameter model, is questionable. In fact, this model presupposes that, regardless of exercise intensity or duration, a fixed percentage of maximal oxygen uptake is immediately available at the onset of exercise and can be sustained throughout the exercise, assuming also that the anaerobic work capacity will be fully used during each exercise bout (11). Thus, extrapolation of the relationship to extremes of intensity or duration requires that some velocity can be sustained for an infinite time and that an infinitely high velocity can be sustained for a very short time. These are unrealistic assumptions and the model may turn out to be inadequate when time to fatigue is less than ~1 min or much greater than 30 min.

Vcri2 seems to be more suitable to determine a intensity possible to be maintained for longer periods of time than Vcri1, for its values are similar to V2000 and the distances applied (200 and 400) are in the range of exhaustion times sustained by Morton (11) and confirmed by Dekerle (3) in swimming: from 2 to 15 minutes, allowing the maximal oxygen uptake to be reached and the anaerobic resources to be depleted. In spite of highly correlated, Vcri2 and V4 did not identify the same power output. In adult athletes, MLSS velocity elicits a blood lactate concentration average of 4 mmol.l⁻¹. For that reason, it has long been estimated by V4 (9). However, MLSS has been reported to have great variability between athletes (from 2-8 min capillary blood) and not to be related to performance (2). Moreover, lactate levels are lower in children than in adults at the same relative exercise intensities possibly due to a lower extravascular increase combined with a faster elimination of the blood lactate concentration dependent on muscle energetic metabolism (1). Therefore a value of 4 mmol.l⁻¹ is too high an estimate of MLSS in children (18). Given that, it can be hypothesised that V4 overestimated MLSS in the subjects of the present study, which ranged in age between 12 and 13 years old.

Improvement in performance, illustrated by V400, was accompanied by similar increases in Vcri2 and V4 velocity and much higher than the observed in V2000, which may reflect the disadvantage of longer tests, where the motivational and volitional capacities of the swimmer are more decisive, especially in younger and less experienced.

Determination of Vcri2 constitutes a useful and accessible evaluation procedure along the season, although the corresponding velocity seems to illustrate a different physiological

intensity from V4. Vcri sensibility to training induced changes in aerobic performance had not yet been verified in age group swimmers.

CONCLUSION

This study confirms the usefulness of Vcri2 as an index of aerobic performance in young swimmers, as wells as a reliable indicator of training induced changes during a competitive season. In spite of the remnant discussion about the metabolic meaning of this parameter, its easy assessment and non invasive characteristics indicates it as an adequate procedure with young swimmers.

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THE FACTORS AFFECTING VELOCITY AT OBLA IN WELL-TRAINED COMPETITIVE SWIMMERS

Yoshimitsu Shimoyama¹, Katsunori Kojima², Hiroshi Ichikawa², Takeo Nomura²

¹Niigata University of Health and Welfare, Niigata, Japan
²University of Tsukuba, Ibaraki, Japan.

This study was intended to investigate the factors affecting velocity at OBLA ($V@OBLA$) in well-trained male college swimmers. Continuous progressive swimming was evaluated at three times (pre-test, mid-test and post-test) to measure VO_{2max} and an intermittent progressive swimming for measuring $V@OBLA$ and stroke length at various velocities. The subjects carried out endurance training for 6 weeks during those tests. The VO_{2max} and $V@OBLA$ values at mid-test and post-test were significantly higher ($p < 0.05$) than those at pre-test. No significant differences in $SL@OBLA$ were apparent among the three tests. Rates of VO_{2max} change correlated significantly ($p < 0.05$); the rate of $SL@OBLA$ change was not significantly correlated with the rate of $V@OBLA$ change. Increasing $V@OBLA$ in this study might be caused not by stroke efficiency improvement but almost entirely by improved aerobic capacity.

Key Words: endurance training, OBLA, stroke length.

INTRODUCTION

It is generally accepted that endurance training should account for a substantial part of swim training for competitive swimming (6). The lactate curve test for measuring the velocity at blood lactate accumulation of 4 mmol/l ($V@OBLA$) is the most precise method for monitoring endurance-training (4). For that reason, the lactate curve test has been conducted periodically during training, and $V@OBLA$ has been used for evaluating the effects of endurance training (7, 9). Wakayoshi et al. (9) demonstrated that stroke length (SL) at 400 m maximal swimming effort was improved by six months of aerobic swim training. Results of previous studies showed that the possibility exists that endurance training can improve not only aerobic capacity, but also stroke efficiency at submaximal velocities. Consequently, $V@OBLA$ measured using the lactate curve test might increase when strokes become more efficient as well as when aerobic capacity improves through endurance training. This study is intended to investigate factors affecting the change in $V@OBLA$ by endurance training.

METHODS

Subjects

Twelve well-trained male college swimmers (19.7 ± 0.8 yrs) participated in this study. They were varsity swim team members who trained for an average of 2-3 h per session, eight times per week. They specialized in freestyle swimming: sprint $n=8$, middle distance $n=2$, and long distance $n=2$. They took part in national level competitions; seven subjects were finalists at competitions. Their mean height, body mass, and body fat percentage were, respectively, 1.80 ± 0.05 m, 73.9 ± 5.5 kg, and $12.4 \pm 2.7\%$. They were informed of the risks of the study and signed a statement giving their informed consent.

Experimental schema

Figure 1 illustrates the experimental schema. The pre-test was carried out at the beginning of the swim training following the off-season, and the mid-test was conducted after the first endurance period of six weeks. The first endurance-training period was designed to fast improvement of aerobic capacity. Approximately 90% of the total training regimen was endurance-type exercise. The weekly training distance was increased gradually from 30 km to 60 km. The post-test was performed six weeks after the second endurance training period. Endurance training accounted for more than 80% of the total training volume. Weekly training distance at this period was approximately 60 km.

Experimental Design

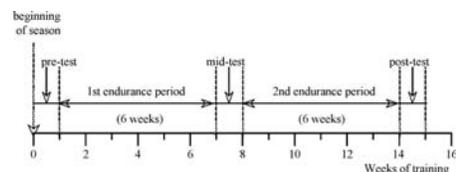


Fig. 1 Experimental schema of this study

All experimental measurements were conducted in a swimming flume using freestyle. A standardized warm-up, which consisted of approximately 2000 m for 30 min, was performed in preparation for each test. Within a week, each subject performed two tests as follows:

1. Continuous progressive swimming test for measuring VO_{2max} ,
2. Intermittent progressive swimming test for measuring $V@OBLA$ and stroke length at various velocities.

Continuous progressive swimming test

Subjects completed continuous progressive swimming tests from submaximal up to exhaustion in a swimming flume for measuring VO_{2max} . The swimming velocity was started at 50% of each swimmer's 400 m personal best. The velocities were increased by 5% every 2 min, up to 60%. They were increased thereafter by 5% every 1 min. An automatic breath gas analyzer (AE-280S; Minato Medical Services Co. Ltd, Japan) with a 10-s sampling rate was used to examine the expired gas continuously during the swimming test to measure the oxygen uptake: VO_{2max} was recorded.

Intermittent progressive swimming test

Subjects performed intermittent progressive swimming tests that consisted of a 3 min swim trial and a 5 min rest period in a swimming flume (5). Subjects were instructed to swim from 60% velocity of each swimmer's VO₂max derived during the pre-test, and increased 5% at each trial up to 100% VO₂max. The SL was measured from 30 s for the last 2 min of each trial using a video camera. Blood lactate was taken from a fingertip immediately after completion of each trial. Blood was analyzed using a blood lactate analyzer (Biosen 5030; EKF Industrie-Elektronik GmbH, Germany).

Statistics

Results were expressed as mean ± standard deviation. One-way analysis of variance with repeated measures (one-way ANOVA test) was used for comparisons among the tests. In cases where significant *F* ratios existed, an additional Fisher's post hoc test was performed. Regression analyses were used to analyze the variables in this study. Statistical significance was inferred for *p* < 0.05.

RESULTS

Figure 2 shows that the mean values of VO₂max at the pre-test, mid-test, and post-test derived from the continuous progressive swimming test. The values of VO₂max measured at the mid-test and the post-test were significantly higher (*p* < 0.05) than those at the pre-test, but no significant difference was found between the mid-test and post-test.

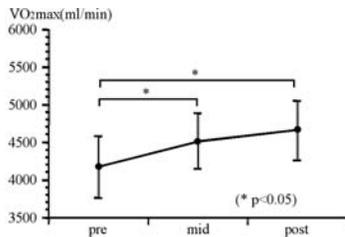


Fig.2 The mean VO₂max at pre-, mid-, and post-test derived from continuous progressive swimming test.

Figure 3 portrays the relationship between swimming velocity and blood lactate concentration in intermittent progressive swimming tests during the pre-test, mid-test, and post-test. Blood lactate concentrations at 85, 90, 95, and 100% VO₂max decreased significantly (*p* < 0.05) from the pre-test to post-test. There was a marked tendency to shift to the right and below at higher velocity from the pre-test to mid-test and post-test.

The relationships between swimming velocity and SL in intermittent progressive swimming test at pre-test, mid-test, and post-test are shown in Figure 4. No significant differences of SL at the same velocities existed between the pre-test, mid-test, and post-test.

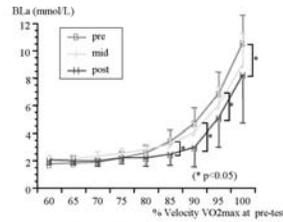


Fig.3 The relationship between swimming velocity and blood lactate concentration in intermittent progressive swimming test.

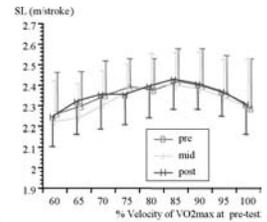


Fig.4 The relationship between swimming velocity and SL in intermittent progressive swimming test.

Figure 5 illustrates the V@OBLA from the results of the intermittent progressive swimming test at pre-test, mid-test, and post-test. The value of V@OBLA at mid-test and post-test were significantly higher (*p* < 0.05) than during the pre-test, but no significant difference was apparent between the mid-test and post-test.

We demonstrate the SL at V@OBLA (SL@OBLA) in Figure 6. No significant differences in SL@OBLA were visible among the three tests.

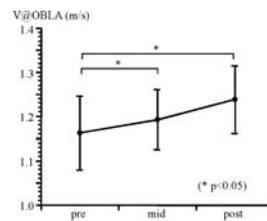


Fig.5 The mean V@OBLA at pre-, mid-, and post-test derived from intermittent progressive swimming test.

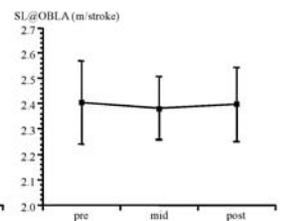


Fig.6 The mean SL@OBLA at pre-, mid-, and post-test derived from intermittent progressive swimming test.

Regarding investigation of the individual changes, we examined the relationship between rates of variable changes from the pre-test to the post-test. Figures 7 and 8 show the simple correlation coefficients between rate of each variable change and rate of V@OBLA change. Rates of VO₂max changed significantly (*p* < 0.05), and were correlated with the rate of V@OBLA change (Figure 7). On the other hand, the rate of SL@OBLA change did not correlate significantly with the rate of V@OBLA change (Figure 8).

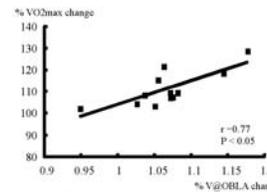


Fig.7 Correlation between rate of V@OBLA change and rate of VO₂max changes from pre- to post-test.

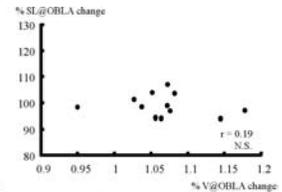


Fig.8 Correlation between rate of V@OBLA change and rate of SL@OBLA changes from pre- to post-test.

DISCUSSION

This study was intended to investigate the factors affecting the change in V@OBLA by endurance training in well-trained male college swimmers. The major finding of this investigation was that the increase of V@OBLA by endurance training is almost

solely explained by improvement of aerobic capacity indicated by VO_2max , not by changing of stroke efficiency that was indicated by SL at various velocities and SL@OBLA in well trained varsity swimmers.

Results shown in Figures 2 and 7 illustrate that VO_2max improved considerably by endurance training from pre-test to mid-test and post-test. Because VO_2max is the most accurate method for measuring aerobic capacity (4), the present results suggest that aerobic capacity was improved by endurance training from pre-test to mid-test, and post-test.

Results of the relationship between swimming velocity and blood lactate concentration in intermittent progressive swimming test (Figure 3) show that blood lactate concentrations at higher velocities were significantly lower in the post-test, despite identical swimming velocity. Moreover, $V@OBLA$ values measured at the mid-test and post-test were significantly higher ($p < 0.05$) than those measured at the pre-test (fig. 5). Previous studies suggested that endurance training would engender reduced lactate production and enhance the efficiency of lactate removal (2, 3). Therefore, it can be inferred that, in the present study, lactate concentrations in muscle and blood decreased at the same submaximal velocities by endurance training.

No significant differences of both SL at the same velocities and SL@OBLA were found between the three tests (Figures 4 and 6). Moreover, the rate of SL@OBLA change did not correlate significantly to the rate of $V@OBLA$ change (fig. 8). Toussaint and Beek (8) suggested that SL gives a fairly good indication of propelling efficiency and might be used to evaluate individual progress in technical ability. Previous studies (1, 9) have demonstrated that endurance training increased SL. They suggested that endurance training engenders improved stroke efficiency. However, the present results were not consistent with those of previous studies. Apparently, this factor was responsible for the difference in the subjects. The present subjects were well-trained male varsity swimmers, including elite swimmers; seven were finalists at national level competitions. Therefore, it seems that the stroke efficiency of such elite swimmers would be already nearly maximized, even at the beginning of the season. On the contrary, the rate of VO_2max change significantly ($p < 0.05$) correlated to the rate of $V@OBLA$ change (fig. 7). These results suggest that, in this study, stroke efficiency would not be likely to improve by endurance training. Therefore, increasing $V@OBLA$ through endurance training was influenced not by stroke efficiency, but by improved aerobic capacity. Similar investigations using various subjects, such as age group swimmers, are necessary to elucidate this point. In conclusion, this study demonstrated that increased $V@OBLA$ by endurance training might be caused not by stroke efficiency improvement but almost entirely by improved aerobic capacity.

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ANALYSIS OF USA SWIMMING'S ALL-TIME TOP 100 TIMES

Genadijus Sokolovas

USA Swimming, Colorado Springs, U.S.A.

The purpose of this study was to investigate the performances of elite level swimmers based on the USA Swimming's All-Time Top 100 times. We analyzed participation of 17-18 years old swimmers at Top 100 from age 10-under until the age of 15-16 years in various events by girls and boys. The data shows that the older the elite swimmer, the more likely he/she will be ranked in the Top 100. About half of the elite swimmers in the Top 100 at age 17-18 were new swimmers who were never ranked in the Top 100 at any age. Most of the future elite swimmers swim slower than age group champions, especially at ages until 15-16 years. Many participant ranked in the Top 100 as age groupers are not present in the Top 100 in the 17-18 age group. We speculate that the two reasons for losing these young Top 100 ranked champions may be related to their early biological maturation and/or an inappropriate training volume at a young age.

Key Words: age group, top 100, performance, swimming event.

INTRODUCTION

There is a paucity of studies on effects of early high-level performances on athletes' progression later in their career (1, 2). The analysis of the all-time Top 100 at different ages may provide valuable information about the long-term progression of elite level swimmers. There is constant debate in the swimming community about high-level performances at a young age in swimming. We still do not know if early high-level performances may limit a swimmer's progression later in their career. Many famous swimmers came from vastly different training programs. Unfortunately, coaches and scientists have speculated about the advantages of low-level or high-level performances at a young age based on a few examples of elite level swimmers. Some elite level swimmers were already ranked in the Top-100 as a 10-under, while other elite level swimmers only reached the Top 100 at age 18. Which strategy is better? The

lack of scientific investigations on long-term performance progression only increases speculation on this topic. The purpose of this study was to investigate the performances of elite level swimmers based on the All-Time Top 100 times.

METHODS

In order to understand the progression of elite swimmers during competition, we analyzed USA Swimming's All-Time Top 100 age group times by girls and boys. All-Time Top 100 age group times are divided into five groups according to the age of the swimmer: 10-under, 11-12, 13-14, 15-16, and 17-18. For the purpose of this study, we considered elite level swimmers the group of All-Time Top 100 at age 17-18. The following swimming events were analyzed: 100, 200, and 500 freestyle; 100 and 200 backstroke; 100 and 200 breaststroke; 100 and 200 butterfly; and the 200 individual medley. The groups of All-Time Top 100 were examined by calculating the percent of participation.

RESULTS

Analysis of Female Top 100 Athletes

All-Time Top 100 in freestyle, backstroke and breaststroke events for females are presented in Figure 1. Data presented for age groups include elite swimmers from Top 100 at age 17-18 in all events. It means that if an elite swimmer from Top 100 at age 17-18 was ranked in other Top 100 events she would be included. For example, if a swimmer was ranked in the Top 100 for the 100 freestyle in the 17-18 age group and was not listed in the Top 100 for 100 freestyle as a 10-under, but was ranked in the 100 breaststroke, she would be included. The 500 freestyle event wasn't included in Top 100 at age 10 and under.

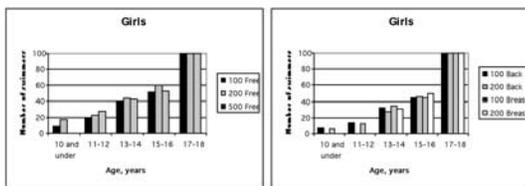


Figure 1. Participation for USA All-Time Top 100 in females' freestyle, backstroke and breaststroke events.

As was expected, the older the elite swimmer is the more likely they will be ranked in the Top 100. However, there were a relatively small number of 17-18 year-old swimmers from the Top 100 who were also ranked as a 10-under. For example, only nine swimmers at age 10 and under were listed at age 17-18 in 100 freestyle. Seventeen swimmers at age 10 and under were listed at age 17-18 in 200 freestyle. The number of elite swimmers slowly increases with each age group in all freestyle distances.

Similar tendencies occur in the stroke events as well. The low numbers of elite female swimmers are listed in backstroke, breaststroke, and fly events (see Figures 1 and 2). These numbers are even lower than in freestyle events and don't reach 50 at age 15-16. Fifty-eight 15-16 year-old girls elite level swimmers were listed in the 200 IM (see fig. 2). These numbers are higher than in other events.

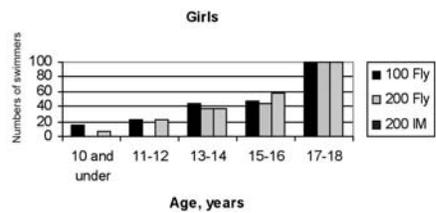


Figure 2. Participation for USA All-Time Top 100 in females' butterfly and IM events.

Analysis of Male Top 100 Athletes

Participation for the USA Swimming All-Time Top 100 in male freestyle events is presented in fig. 3. As the data shows, participation of elite male swimmers is relatively low in each age group until the age of 17-18.

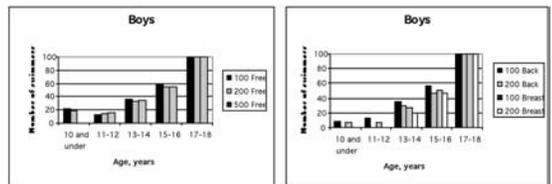


Figure 3. Participation for USA All-Time Top 100 in males' freestyle, backstroke and breaststroke events.

Similar tendencies appear in other males' events (see fig. 3 and 4).

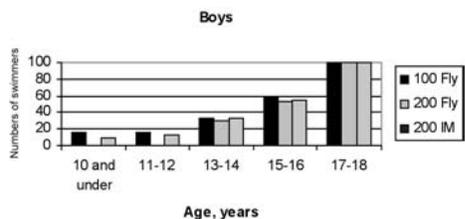


Figure 4. Participation for USA All-Time Top 100 in males' butterfly and IM events.

DISCUSSION

The analysis shows that most of elite level swimmers were unknown at young ages. Most of the future elite swimmers swim slower than age group champions, especially at ages until 15-16 years. Many participants ranked in the Top 100 as age groupers are not present in the Top 100 in the 17-18 age group. We speculate that the two reasons for losing these young Top 100 ranked champions may be related to their early biological maturation and/or an inappropriate training volume at a young age (1, 6, 8, 9). Higher participation on 500 compared to 100 and 200 freestyle events in the 11-12 group may be attributed to larger contribution of aerobic energy system at younger ages (1, 2, 11). Young athletes have lower anaerobic power and are not able to accumulate high blood and muscle concentrations (3, 4, 5, 6). Surprisingly, there were still a low number of elite swimmers

at age 15-16 for girls and boys. About half of the elite swimmers in the Top 100 at age 17-18 were new swimmers who were never ranked in the Top 100 at any age. This statistic shows that most of the future elite swimmers swim under Top 100 times until age 15-16.

There is a small difference between elite female and male freestyle swimmers at age 11-12 and 13-14, where it appears that higher numbers of female freestylers were ranked in the Top 100. Higher numbers for females may be related to earlier biological maturation in girls (6, 7, 10).

It was investigated how many elite level swimmers change their events at Top 100's. With that goal in mind we analyzed participation of elite swimmers from age 17-18 in Top 100's at various ages in the same and other events. For example, how many elite swimmers from age 17-18 were listed in the same or other events at age 10 and under, 11-12, 13-14, and 15-16. It is better to look at these numbers relative to the total number of elite swimmers. At age 10 and under many elite female swimmers are listed in other events. As data shows, 51.6% of elite female swimmers are listed in other events at age 10 and under. This number decreases with age and reaches 37.9%, 26.6% and 24.9% at age 11-12, 13-14 and 15-16, respectively. It shows that most of elite female swimmers select their event at age 13-14.

The analysis of elite male swimmers shows that 69.6% of elite male swimmers are listed in other events at age 10 and under. This number decreases with age and reaches 55.6%, 40.8% and 26.7% at age 11-12, 13-14 and 15-16, respectively. Thus, the elite male swimmers select their events at age 15-16 or about 2 years later than elite female swimmers.

CONCLUSIONS

1. A small number of elite swimmers from the Top 100 at age 17-18 were ranked in the Top 100 at a younger age. Typically, a little over 10 % were ranked as a 10-under, about the same figure as a 11-12 year old, a little over 30% as a 13-14 year old, and a little over 50% as a 15-16 year old. Similar numbers were found for female swimmer's, however, they have a little higher percentages in the 11-12 and 13-14 age groups.

2. The analysis shows that most of elite level swimmers were unknown at young ages. About a half of elite swimmers at Top 100 at age 17-18 are new swimmers, which never were listed at Top 100 at any age. This leads to conclusion that most of future elite swimmers swim slower than age group champions, especially at ages until 15-16 years.

3. Many participants ranked in the Top 100 as age groupers are not present in the Top 100 as they become an elite swimmer in the 17-18 age group. We speculate that the two reasons for losing these young Top 100 ranked champions may be related to their early biological maturation and/or an inappropriate training volume at a young age.

4. Elite level swimmers change their events during long-term training. Elite female swimmers tend to change their events until the age of 13-14. Elite male swimmers tend to change their events until the age of 15-16.

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ENERGY EXPENDITURE AND FOOD INTAKE OF COMPETITIVE SWIMMERS DURING TRAINING

H. Soultanakis¹, M. Mandaloufas^{1,2}, T. Platanou¹

¹Faculty of Physical Education and Sport Sciences, Aquatics Department, University of Athens, Greece

²Greek Swimming Federation, Greece.

Poor dietary practices may accumulate and lead to deficiencies that may influence performance during training. The purpose of this study was to investigate whether the dietary intake of elite swimmers can match the energy and nutrient requirements of training. Dietary habits were evaluated in 16 elite swimmers (6 male, 10 female). Diet content and energy expenditure were estimated by using 3-day weighed dietary and activity records. Their three day training averaged 7.568 m of swimming per day. The total energy cost averaged 3146.88 ± 494.10 kcal/day. Diet records revealed that the swimmers consumed daily 2182.25 ± 964.14 kcal/day, approximately 800 kcal less than their daily requirements. Protein intake was approximately double their energy cost. The results demonstrated the inability of swimmers to maintain a balanced diet.

Key Words: swimming, energy expenditure, food intake.

INTRODUCTION

During times of high physical activity, energy and macronutrient needs—especially carbohydrate and protein intake—must be met in order to maintain body weight, replenish glycogen stores, and provide adequate protein for building and repair of tissue (9). Poor dietary habits can influence the performance of swimmers during training. Repetitive sessions of high intensity

swimming can deplete glycogen stores and important vitamins, minerals and other nutrients. In a study to assess the effect of increased training volume on nutrient intake of male collegiate swimmers it was found that energy intake did not fully compensate for expenditure, as both groups maintained weight but lost subcutaneous fat (1). Insufficient energy and carbohydrate intake have also been recorded in triathletes and other athletes. When the nutritional habits of young adolescent swimmers were evaluated, swimmers appeared to consume too much fat and not enough carbohydrate even though they consumed enough nutrients (2). It appears that individual swimmers may have very poor dietary habits and thus may not be providing adequate fuel or nutrients for optimal training or performance. The great emphasis placed on nutritional supplements underestimates the importance of nutrition. The purpose of this study was to evaluate whether dietary intakes of elite swimmers can match the energy and nutrient requirements of training.

METHODS

Sixteen (6 male, 10 female), elite teenage swimmers participated in this study. Food intake and energy expenditure were calculated through the completion of three-day weighed dietary records and activity records. Energy expenditure was estimated indirectly by taking into account the basal metabolic rate (BMR), the thermic effect of food, and energy expenditure of daily activities and swimming training. The energy expenditure of swimming was estimated indirectly taking into consideration the body mass of the swimmer, the intensity, the duration and the strokes swam (on types, duration and intensity of training) (9). Food was categorized in terms of quantity and nutrient content in order to be assessed. Food intake was analyzed by computer analysis (Food Processor II, Esha Research) for its caloric content, carbohydrate, fat, protein, dietary fiber, and saturated fat. Energy expenditure estimations were based on the Food and Agricultural Organization equations and exercise metabolic rate was calculated through the reported training records (on types, duration and intensity of training). Daily energy requirements were estimated by distributing the total calculated energy expenditure (calories) into the recommended percentages of a balanced meal (i.e.:60-70% carbohydrate, 15-20% fat and 15-20% protein). Data were statistically analyzed by a Pearson's r correlation coefficient test.

RESULTS AND DISCUSSION

Swimmers had a mean age of 18 ± 1.4 yr, a mean height of 176.13 ± 8.34 cm and a mean weight of 66.19 ± 13.19 kg. Their three day training distance averaged 7.568 meters per day. The mean dietary intake was significantly lower than the estimated energy expenditure of swimming and protein intake was almost double the energy cost of swimming. Carbohydrate showed lowering but non-significant trends and fat didn't demonstrate any significant differences (table 1).

Table 1. Dietary Intake and Energy Expenditure and during a 3-day training period.

Variables	Dietary Intake and Nutrient Content	Energy Expenditure and Daily Estimated Requirements
Calories (Kcal)	2182.25* \pm 964.14	3146.88 \pm 494.10
Protein (g)	103.23* \pm 41.59	52.96 \pm 11.18
Carbohydrate (g)	262.38 \pm 125.08	456.19 \pm 71.57
Fat (g)	88.43 \pm 49.67	104.89 \pm 16.25
Dietary fiber (g)	18.24 \pm 8.32	31.45 \pm 4.94
Saturated Fat (g)	34.10 \pm 20.66	34.95 \pm 5.49

*Denotes that means are significantly different ($p < 0.05$) from the Energy Expenditure values.

It is well established that the nutritional requirements of training are far more demanding than those required for competition in short distance swimming. Poor daily dietary practices may accumulate and lead to deficiencies that may influence the improvement of performance. Many swimmers nowadays rely on nutritional supplements to counterbalance a poor diet without evaluating first the quality of their food intake. This study demonstrated that the energy and nutrient requirements of training do not match. One of the fundamental differences between an athlete's diet and that of the general population is despite the greater fluid needs, that athletes require additional energy to fuel physical activity more so than the increased needs for other nutrients. It is considered appropriate for much of the additional energy to be supplied as carbohydrate. Caloric deprivation is often accompanied with carbohydrate deficiency and decrements in swimming training performance (3). In recent studies evaluating the dietary intake and nutritional practices, swimmers of both gender consumed too much fat and protein and too little carbohydrate (7, 9). Carbohydrates in this study showed some lowering trends which however were not significant (fig. 1). Percent distribution of the three major nutrients may not always be the best recommendation for athletic populations particularly in application to female athletes whose caloric requirements are lower and proportionally the amount of carbohydrate will be lower.

In a study evaluating the dietary intakes of age-group swimmers although the contribution of carbohydrate to total daily energy intake was the same for male (55%) and female swimmers (56%), the females ingested significantly less carbohydrate (292g) than the males (404g) and could be considered deficient in dietary carbohydrate with respect to their daily training demands (5). In this study swimmers' carbohydrate consumption showed some lowering but non-significant trends but had an excess of protein intake (fig. 1).

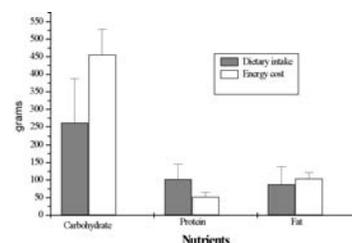


Figure 1. Dietary intake and energy cost of swimming during training.

As previously reported, the calculated energy expenditure of female athletes was greater than the reported energy intakes and as a consequence those with very low intakes reported menstrual abnormalities (6). The caloric deficiency that was evident in the present study can eventually lead to carbohydrate deficiency, whereas the excess of protein intake may unnecessarily tax the system. Swimmers are usually not well informed on balanced nutritional practices that would give them an edge during training and eventually during competition. They need to be better informed and eventually learn to value the priority of well balanced meals over supplementation. Their daily practices are demonstrating their inability to maintain a balanced diet, especially when taking into consideration the fact that most consumed an overabundance of food supplements including vitamins, protein and amino acids. Nowadays, it is well established, that if energy intake is high and a varied diet is consumed, supplementation of the diet with vitamins and minerals is not necessary, unless a specific deficiency is identified (1).

CONCLUSIONS

Nutritional evaluation of individual swimmers is not practiced routinely by coaches, swimmers or parents. Well balanced diets are necessary for swimmers of all categories and levels of competitiveness. The over-consumption of supplements may not necessarily cover all the needs of swimmers especially their energy requirements (calories), as well as their carbohydrate requirements. Too often, supplements may provide a fast boost of energy masking the real deficiencies and true requirements of the swimmer. The negative impact that a majority of supplements may have on the swimmer's health should not be underestimated. The adoption of a well balanced diet with plenty of hydration and the estimation of the energy expenditure of every swimmer individually will aid for better performances and healthier athletes.

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DIFFERENT LEVELS OF HYDRATION FOLLOWING A TRAINING SESSION ON SWIMMING PERFORMANCE

Argyris Toubekis, Nikoleta Christoforou, Konstantinos Lapidis, Theoharis Tahtalis, Savvas Tokmakidis

Department of Physical Education and Sport Sciences, Democritus University of Thrace, Komotini, Greece.

This study examined the effects of two different levels of hydration after a training session on subsequent performance. Eight swimmers performed a morning swimming training session, and 8 hours later a testing session of 4x200m at an intensity of 95% of the critical velocity (4x200submax) and 200m maximum effort (200max). In two separate trials, swimmers consumed a fluid volume of either 150% (F150) or 50% (F50) of the morning post-training body mass (BM) loss. BM was reduced by $0.9 \pm 0.2\%$ and $0.8 \pm 0.3\%$ after the morning session in F150 and F50 trials respectively ($p > 0.05$). Eight hours later, BM had recovered in the F150 but not in the F50 trial ($p < 0.05$). Heart rate showed a tendency to increase at the end of the 4x200submax ($p = 0.08$). The 200max time was not different between trials ($p > 0.05$). As a result dehydration of 1% might not be a critical factor in impairing performance during a 200max.

Key Words: fluid loss, recovery, hypohydration.

INTRODUCTION

High intensity swimming training of long duration will cause dehydration (2). This may affect swimming performance as it has been observed in cycling (5); proper hydration is, therefore advisable. The effect of dehydration on performance in other types of exercise is well-documented (4). However, there is no available data on swimming performance. Most of the swimmers participate in training twice a day with a recovery period of about 8 hours. The volume of fluids consumed after a training session can be crucial for rehydration and performance on a following session (3, 4). The purpose of the study is to examine the effect of two different levels of hydration after a training session on performance eight hours later in a subsequent afternoon session.

METHODS

Eight male swimmers (mean \pm SD, age: 21.4 ± 1.2 yrs, height: 179 ± 6 cm, body weight: 74.8 ± 4.3 kg, VO_{2max} : 3.98 ± 0.30

l/min) participated in the study. They had past competitive swimming experience but trained recreationally during the examination period. The swimmers performed, on two separate days, a 400m maximum effort and a series of 5x200m with progressively increasing intensity up to maximum effort starting every seven minutes. Expired air was collected breath by breath (Oxycon Jaeger, Germany) during the recovery period for the determination of the VO_2max and for the velocity vs. O_2 uptake relationship. Critical velocity (CV) was calculated from the time of the 400m and the last of the series of 5x200m test. On a third visit to the swimming pool a familiarization training of about 3000m was performed.

Swimmers participated in a morning swimming training session of 4800m (intensity range: 95-105% of CV, table 1), followed 8 hours later by an afternoon testing session of 4x200m at an intensity of 95% of the CV (4x200submax, table 1) and ten minutes later by a 200m maximum effort (200max). No fluid consumption was allowed during morning or afternoon sessions. In two separate trials a week apart, and during the 8 hours recovery between the morning and afternoon sessions, swimmers consumed a fluid volume (carbohydrate-electrolyte solution, isostar® 6%) of either 150% (F150) or 50% (F50) of the morning post-training body mass (BM) loss.

Table 1. The training contents of the morning training and afternoon testing sessions.

Morning training session			Afternoon testing session		
Repetitions	Recovery (s)	Intensity (% of the CV)	Repetitions	Recovery (s)	Intensity (% of the CV)
8x200m	20 180 after the set	95	4x200m	20 10 min after the set	95
6x200m	30 180 after the set	100	1x200m		maximum
2x(4x100m)	15 (90 after set 1)	105			
400 leg kick					

CV: critical velocity.

Swimmers fasted for the morning session and their nude BM was measured with an accuracy of 0.1kg. At the completion of the morning training session, swimmers dried their body and hair and were reweighed nude. The BM was again measured before the afternoon session. Before each BM measurement the urine bladder was emptied and urine volume was measured. Breakfast was provided after the completion of the morning session (1gr/kg of BM solid plus 100ml of fluids) and was controlled for the carbohydrate (CHO) content. Following breakfast, swimmers were advised to consume the prescribed fluid volume at regular intervals during the 8-hour recovery period and to avoid any other fluid consumption. Urine volume was collected and measured at the end of this period. Blood lactate was determined at the end of each training set (Dr Lange M8; Berlin Germany) and blood glucose (LifeScan, Sure Step plus) was measured before and after each training session and 30 min after breakfast (60 min after the end of training). Heart rate (HR) was recorded continuously during both sessions (Polar x-Trainer plus). Diet was recorded two days before the testing days and during the 8 hours of recovery. All tests took place in a 50m indoor swimming pool with air and water temperature of 23-25 °C and 27°C, respectively. Relative humidity was 80-85%. The front crawl swimming style was used during testing. A two-way analysis of variance for repeated measures

or a student t-test (200max) was used for the statistical analysis. The Tukey post-hoc test was used to locate differences between variables. The results are presented as mean±SD and the accepted level of significance was set at $p<0.05$.



Figure 1. The experimental procedure of the study.

RESULTS

The CV of the swimmers ($1.183\pm 0.080\text{m/s}$) corresponded to $85\pm 7\%$ of the VO_2max and to $93\pm 4\%$ of the velocity of the maximum 400m time. The training sets were prescribed at the range of 95-105% of the CV and this intensity varied from $80\pm 7\%$ to $90\pm 7\%$ of the VO_2max . Blood lactate and glucose as well as HR were similar during the morning session in both trials (fig. 2 and fig. 3, $p>0.05$).

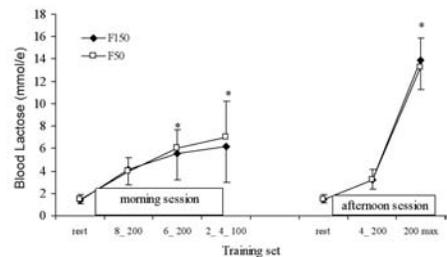


Figure 2. Blood lactate concentration during swimming trials. * $p<0.05$ compared with the previous training set of the same session (mean±SD, n=8).

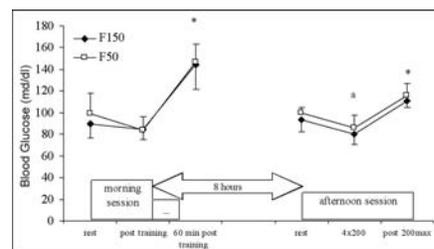


Figure 3. Blood glucose responses during swimming trials. * $p<0.05$ from the previous sampling point. a $p<0.05$ between trials, B: breakfast (mean±SD, n=8).

BM was reduced by $0.9\pm 0.2\%$ and $0.8\pm 0.3\%$ after the morning session in F150 and F50 trials, respectively (between trials, $p>0.05$). Swimmers ingested 1050 ± 175 and $306\pm 112\text{ml}$ of fluids and the urine output was 481 ± 186 and $304\pm 121\text{ml}$ in the F150 and F50, respectively ($p<0.05$). At the beginning of the afternoon session, 8 hours later, BM had recovered in the F150 but remained decreased in the F50 trial (fig.4, $p<0.05$).

HR showed a tendency to increase at the end of the 4x200submax ($p=0.08$) and was higher in the afternoon testing compared to the morning session in the F50 trial (fig. 5, $p<0.05$). The swimming time to cover the 200max was not different between trials (F150:143.54 \pm 5.92 vs. F50:144.29 \pm 4.30s, $p>0.05$).

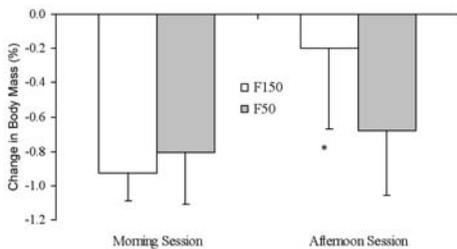


Figure 4. Body mass changes after the morning training session and before the afternoon session * $p<0.05$ on F150 trial (mean \pm SD, n=8).

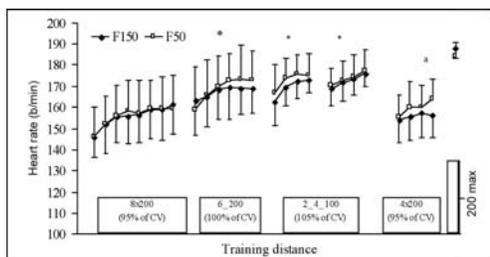


Figure 5. HR responses during the morning and afternoon training sessions. * $p<0.05$ from the previous training set, a $p<0.05$ from the first repetition (mean \pm SD, n=8).

DISCUSSION

Ingestion of fluids equal to 150% of the BM loss is marginally adequate, while a fluid volume of 50% of the BM failed to restore fluid losses. In this case, swimmers may appear in a subsequent session partially or severely dehydrated. However, this level of dehydration (i.e. 1%) may not be a critical factor in impairing performance during a 200m maximum swimming effort or in altering HR responses during submaximal exercise (5). Even though the BM before the afternoon testing session was not statistically different from the morning pre-training BM, incomplete recovery was still present from the previously induced dehydration. This is probably attributed to the sodium content of the consumed beverage. Increased sodium concentration will enhance the rehydration process when a volume corresponding to 150% of the fluid loss is consumed (3, 4). Nevertheless, the rehydration was better accomplished in the F150 compared to F50 trial. In addition, due to the controlled CHO content during the recovery period of both trials, any changes in performance in the afternoon testing session could be attributed to the different levels of hydration. However, performance was not different between trials. It has been suggested that a dehydration of more than 1% will cause deterioration in performance (3, 4), regardless previous data had suggested that aerobic exercise performance was not impaired with hypo-

hydration of 2% (5). In the present study the type of aerobic exercise performed was of short duration (15min) and the swimming pace (95% of the CV) was easily maintained but with a tendency for increased HR in the F50 trial. It is likely that the consequences of dehydration on the cardiovascular system would have reached significant levels if the duration of this testing set (4x200submax) was extended. No difference in performance was observed in the 200max test. A high percentage of anaerobic contribution is incorporated in this swimming distance and it is likely that a more severe dehydration (<4%) is needed to impair performance during short duration (>3min) exercise (1,5).

CONCLUSION

The volume of fluid consumed after a swimming training session should exceed 150% of the total body weight loss. Dehydration of 1% may not be a critical factor in impairing performance during a maximum 200m swimming effort. This level of dehydration may, however, alter HR responses during submaximal swimming.

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DETERMINATION AND APPLICATION OF INTERVAL SWIM CRITICAL VELOCITY AND CRITICAL REST TIME IN THE 50M INTERVAL SWIM TRAINING

Kohi Wakayoshi¹, Chiharu Takano¹, Futoshi Ogita²

¹Nara University of Education, Nara, Japan

²National Institute of Fitness and Sports, Kanoya, Japan.

The purpose of this study was to determine critical velocity (V_{critS}) and critical rest time (t_{cri}) for interval training at four velocities higher than anaerobic threshold. Eleven well-trained college male swimmers performed four to six sets of 50m interval swim test (T_{int}) at each given velocity. The relations between total time (t_T) and the total swim distance (D_{int}) of T_{int} were expressed in the general form, $D_{int}=a+b*t_T$ in all subjects. V_{critS} could be determined by the relationship between D_{int} and t_T . and t_{cri} could be calculated from V_{critS} and swimming time (t_s) at each velocity. Moreover, combination swimming velocity, rest time and total swimming distance direction could be determined. It was thought that the combinations of velocity and rest period which imply interval training fatigue

threshold (ITFT) could be defined from the results of V_{critS} and t_{cri} .

Key Words: interval swim, critical velocity, critical rest time.

INTRODUCTION

Interval training is the training method utilized most frequently for swimmers and coaches. Maglischo (1993) has proposed several guidelines for the interval training categories, consisting of set distances, repeated distances, rest intervals, speed and total distance per week for improving power, anaerobic and aerobic metabolism.

The concept of critical velocity (V_{cri}) determined by the relationship between the swimming distance and the swimming time has been utilized for the many studies that investigated relations of V_{cri} , aerobic endurance, maximal lactate steady state and critical stroke rate (2, 3, 4, 5). Moreover, the interval swim critical velocity (V_{critS}) defined as the maximal average speed to be able to swim repeatedly without exhaustion in the 50m interval swim training at one swimming velocity higher than anaerobic threshold could be determined and the critical rest time (t_{cri}), which could theoretically be repeated the interval swims without exhaustion could be estimated by using V_{critS} (7). It was thought that V_{critS} could be applied as an index for setting the combination of swim velocity and rest time for the interval training, matching to the performance level of the swimmers.

In the present study, the purpose of this study was to determine V_{critS} and t_{cri} for interval swim training at four swimming velocities higher than anaerobic threshold and to apply those data to an index for setting the combination of swim velocity, rest time and swimming distance for the interval training.

METHODS

1. Subjects. The subjects who volunteered for this study were 11 well-trained college male swimmers (19-21 years). The subjects were informed of the risks involved in participating in the study and signed a statement of informed consent.

2. 50m and 2000m max swim tests. All swim tests were performed using the front-crawl stroke and started from the water in the 50m pool. Subjects were instructed to swim 50m and 2000m with maximal effort. The mean velocity (mean velocities of 50m and 2000m; V_{50} and V_{2000}) was determined for each subject. In principle, these maximal effort tests were performed with one event swum per day.

3. 50m interval swim test and determination of V_{critS} and t_{cri} .

The subjects had 50m interval swim test (T_{int}). The swimming velocity in T_{int} were set at four paces of $V_{30\%}$, $V_{40\%}$, $V_{50\%}$ and $V_{60\%}$ for each subject, which were calculated by the following equation, $V_{30\%}$ as an example, $V_{30\%} = 0.3(V_{50} - V_{2000}) + V_{2000}$. A light pace marker was used to ensure compliance with predetermined velocity. If the subject could not complete interval swim 30 times in each T_{int} , the rest time was increased by 2-10 s in the next trial, until the subjects could complete T_{int} . The T_{int} was terminated when the head position of the swimmer was 1 m away from lights of the pace marker during the test. When two sets of the T_{int} were done in a day, the subject was allowed to rest for at least 3 hours between trials. Finally, the subjects performed three to six sets of T_{int} at each velocity. The total time (t_T) of T_{int} including interval swims and rest periods

and the total swim distance (D_{int}) of T_{int} were determined.

Table 1 shows t_T and D_{int} of T_{int} at $V_{50\%}$ for subject 11 and the relationship between D_{int} and t_T for determining V_{critS} is illustrated in Figure 1. Subject 11 could not complete T_{int} with rest durations of 5s, 10s, 15s and 20s and could complete T_{int} with rest durations of 25s and 30s. Those points were accurately situated on a line defined by the relationship between D_{int} (D) and t_T (T).

Table 1. t_T and D_{int} of T_{int} at $V_{50\%}$ for subject 11.

Rest time	5s	10s	15s	20s	25s	30s
D_{int} (m)	219	274	479	950	1500	1500
t_T (s)	155.5	219.7	431.7	968.2	1678.8	1828.8

The equation of regression line can be expressed as follows:

$D = a \cdot T + b$

Swimming velocity (V) multiplied by T makes D and D can be substituted by V·T;

$D = V \cdot T, V = a + b/T$

Theoretically, if we could set the interval swim at which one can perform indefinitely ($T \rightarrow \infty$), b/T will be approach zero and V will approach a. Therefore, V_{critS} can be expressed as the slope of the regression line:

$V_{critS} = a$

V_{critS} in T_{int} at $V_{30\%}$ for some swimmers could be determined by the relationship between D and T of two points, because they could complete interval swim with shorter rest duration.

V_{critS} has been defined as the maximal average speed to be able to swim repeatedly without exhaustion. t_{cri} for interval swim, which can theoretically be repeated the interval swims without exhaustion in T_{int} at $V_{50\%}$, can be estimated by using V_{critS} . In the present study, swimming time (t_s) of 50m for T_{int} was calculated with the following equation:

$t_s = 50/V_{50\%}$

Theoretically, V_{critS} multiplied by the cycle time ($t_s + t_{cri}$) makes repeated distance of T_{int} (50m) and t_{cri} can be estimated:

$V_{critS} \cdot (t_s + t_{cri}) = 50, t_{cri} = 50/V_{critS} - t_s$

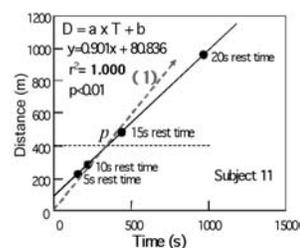


Figure 1. Relationship between swimming distance and total time of interval swim test.

5. Combination of swimming velocity, total swim distance (D_T) and rest time (t_R). Combination of swimming velocity, D_T and t_R could be determined from the equation of regression line between D_{int} (D) and t_T (T).

If we set 400m as D_T , total time (T) can be calculated by using the equation of regression line in Figure 1:

$400 = 0.901 \cdot T + 80.836, T = 354.3s$

A straight line to pass the origin and point p (354.3, 400) can

be expressed:
 $y=1.129x (1)$

The slope of line (1) is maximal average velocity which swimmer can swim 400m at $V_{50\%}$. Therefore, the shortest rest time (t_{cr400}) which swimmer can repeat 8 times ($D_T=400m$) of interval swims at $V_{50\%}$ can be calculated:
 $1.129(t_{R400} + 31.0)=50, t_{R400}=13.3$

RESULTS

Table 2 shows the swimming style and the results of the tests for each subject. Significant correlations were found between D_{int} and t_T at $V_{40\%}$, $V_{50\%}$ and $V_{60\%}$ in all subjects. Moreover, there were significant correlations between D_{int} and t_T for subjects who had three sets of T_{int} with exhaustion at $V_{30\%}$.

Table 2. The performance and test results for each subject.

Sub ject		V_{30} (m/s)	V_{40} (m/s)	V_{50} (m/s)	Laers (s)	V_{30} (m/s)	V_{40} (m/s)	V_{50} (m/s)	Laers (s)	V_{30} (m/s)	V_{40} (m/s)	V_{50} (m/s)	Laers (s)
1	F-L	1.81	1.27	1.16	8.2	1.16	10.4	0.91	22.4	0.87	26.1		
2	F-L	1.85	1.38	1.30	5.8	1.19	8.3	1.02	18.0	0.87	27.2		
3	I-L	1.72	1.31	1.22	6.3	1.09	12.0	0.96	19.4	0.89	24.0		
4	F-L	1.81	1.30	1.17	8.4	1.06	13.7	1.01	17.5	0.86	27.1		
5	F-M	1.95	1.38	1.14	11.6	0.91	17.8	1.02	19.2	0.98	27.9		
6	F-M	1.86	1.25	1.19	7.1	1.07	13.1	0.91	22.6	0.87	26.3		
7	I-M	1.81	1.26	1.20	6.5	1.03	14.6	0.92	21.5	0.93	22.2		
8	F-M	1.85	1.22	1.18	7.0	1.07	12.8	0.90	22.9	0.90	24.6		
9	I-S	1.61	1.07	0.99	9.7	0.90	16.8	0.73	31.1	0.70	35.5		
10	F-S	1.90	1.23	1.10	10.5	1.00	16.6	0.86	26.2	0.74	36.9		
11	F-S	1.91	1.32	1.10	12.1	0.95	20.3	0.90	24.5	0.74	37.7		
Mean		1.82	1.27	1.16	8.5	1.04	14.2	0.92	22.3	0.85	28.7		
SD		0.09	0.09	0.08	2.2	0.09	3.5	0.08	4.0	0.09	5.4		

I: individual medley, B: breaststroke, F: freestyle, S: 50m or 100m, M: 200m, L: 400m-.

Fig. 2A illustrates the relationship between individual t_{cri} and swimming velocity at $V_{30\%}$, $V_{40\%}$, $V_{50\%}$ and $V_{60\%}$ for all subjects. There was a tendency that t_{cri} at all velocities of the short distance swimmers were remarkably longer than those of the middle and long distance swimmers.

Mean values of $t_{cri30\%}$, $t_{cri40\%}$, $t_{cri50\%}$ and $t_{cri60\%}$ in the short distance groups and the long distance groups were 10.8s (SD 1.2), 17.9s (SD 2.1), 27.3s (SD 3.4) and 36.7 (SD 1.1), and 7.2s (SD 1.3), 11.1s (SD 2.3), 19.3s (SD 2.2) and 26.1s (SD 1.5), respectively. In Fig. 2B, those data were plotted and the approximation curve line passed through the point of intersection and those data of each group was shown.

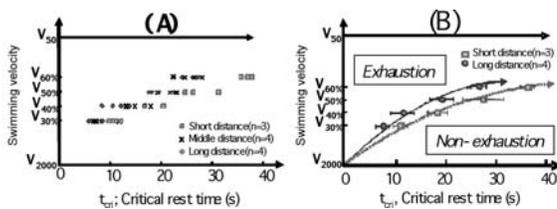


Figure 2. Relationship between t_{cri} and swimming velocity for all subjects (A) and relationship between mean values of t_{cri} in the short distance groups and the long distance groups and swimming velocity (B) at $V_{30\%}$, $V_{40\%}$, $V_{50\%}$ and $V_{60\%}$.

Figure 3 illustrates the combination of swimming velocity at $V_{30\%}$, $V_{40\%}$, $V_{50\%}$ and $V_{60\%}$, t_R and D_T of 200m (50m x 4t), 400m (50m x 8t) and 1000m (50m x 20t) determined from the equation of regression line between D_{int} and t_T for all subjects.

Moreover, the approximation curve line passed through maximal swimming velocity of D_T at 0 rest time and those data plotted relations between swimming velocity and rest time points of each D_T was drawn.

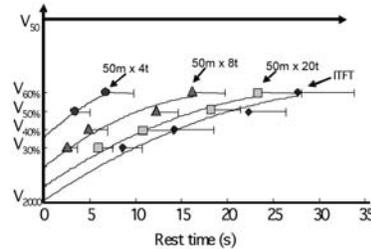


Figure 3. Combination of swimming velocity at $V_{30\%}$, $V_{40\%}$, $V_{50\%}$ and $V_{60\%}$, rest time and total swimming distance of 50m x 4t, 50m x 8t and 50m x 20t.

DISCUSSION

V_{critS} defined as the maximal average speed to be able to swim repeatedly without exhaustion in the 50m interval swim training at a given velocity higher than anaerobic threshold could be determined and t_{cri} , which could theoretically be repeated the interval swims without exhaustion could be estimated by using V_{critS} (7). The primary goal of this study was to determine V_{critS} and t_{cri} for interval swim training at four velocities higher than anaerobic threshold and to apply those data to an index for setting the combination of swim velocity, rest time and swimming distance for the interval training.

We had two to five sets of T_{int} at given velocities to calculate V_{critS} for each subject. A strong correlation between D_{int} and t_T was found for all subjects except a part of T_{int} at $V_{30\%}$, so that the certain linear relationship $D_{int}=a+b \cdot t_T$ was obtained. Therefore, V_{critS} and t_{cri} at four swimming velocities could be determined for all subjects.

t_{cri} of the long distance swimmers at four velocities were remarkably shorter than those of short distance swimmers and the relation between swimming velocity and t_{cri} was shown the approximation curve line at each group. V_{2000} of intersection in Figure 2 and 3 almost corresponds to the swimming velocity at maximal lactate steady state (2, 5) and continued to swim without exhaustion. In the results of this study, it can be hypothesized that the approximation curve line indicates fatigue threshold in relation to swimming velocity and rest period for the interval training, and approaches asymptotically to the level at V_{50} along with the extension in rest interval. Consequently, the interval training combined swimming velocities and rest intervals below the curve it possible for the swimmer to swim repetitiously without exhaustion. The interval training performed at combinations above the curve, on the other hand, does not make it possible to swim repetitiously with exhaustion. In the present study, we named the curve in Figure 2B as "Interval Training Fatigue Threshold" (ITFT). Moreover, combination of swimming velocity, rest time and total swimming distance could be determined from the equation of $D_{int}=a+b \cdot t_T$.

CONCLUSION

It is thought that the application of ITFT concept could be a

helpful index for the coach and swimmer, in order to determine precisely and easily the combinations of the individual swimming velocity, rest time, repeated distance and number of repetitions, taking account of the fatigue characteristics and the performance level of the swimmers.

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