University School of Physical Education in Wrocław
University School of Physical Education in Poznań

HUMAN MOVEMENT

formerly

Człowiek i Ruch (Human Movement)

vol. 8, number 2, 2007

Akademia Wychowania Fizycznego we Wrocławiu (University School of Physical Education in Wrocław)
Akademia Wychowania Fizycznego im. Eugeniusza Piaseckiego w Poznaniu (University School of Physical Education in Poznań)

HUMAN MOVEMENT
formerly Człowiek i Ruch (Human Movement)
vol. 8, number 2, 2007, pp. 75–154

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Proofreading: Halina Marciniak

Indexed in: SPORTDiscus, Index Copernicus, Altis, Sponet

ISSN 1732-3991

http://www.awf.wroc.pl/hum_mov

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Print: Agencja Reklamowa i Drukarnia KONTRA
Circulation: 300

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HUMAN MOVEMENT
2007, vol. 8 (2)

EDITORIAL

The articles in the present volume of *Human Movement* prove the commitment of the Editorial Board to broaden the thematic scope of the journal devoted to human motor activity. The papers discuss the structure and dynamics of human movement, psychological aspects of physical activity and elements of sport didactics.

One of the most interesting interdisciplinary articles in the volume focuses on relationships between physical fitness and selected personality traits in adolescents, as well as their gender-related diversification. Personality traits determining the level of physical fitness are also inquired.

Two papers are concerned with psychological aspects of performing sports. A comparative analysis of temperament of chess players and football players shows that the former mostly feature a relatively high level of nerve processes stimulation strength and a much more differentiated level of mobility for these processes. However, football players are also characterized by substantially high levels of nerve processes stimulation as well as their high mobility. The other paper discussing differences in experiencing relaxation by coaches shows that coaches of individual sports are better prepared to achieve a deeper state of relaxation. Relaxation techniques can be extremely useful for development of constructive stress management programs in all phases of coaches' work. However, the knowledge of the subject, which can be applied to develop some practical stress management strategies, is still very limited.

The present volume also contains three articles on assessment of motor function of swimmers representing different sports levels. A study of kinematic parameters of finalists of the European Championships shows that the knowledge of individual movement technique parameters enables a thorough evaluation of the competitor's training level and makes it possible to adjust it to model standards. A paper examining selected structural and functional indices of young swimmers shows that front crawl swimming speed is dependent on swimming technique, i.e. it is modified by the swimmer depending on the swimming distance. Mastery of an efficient technique also determines the levels of somatic indicators and athlete's physiological abilities.

The third article on motor function assessment is a comparative study of selected properties of elbow and knee flexors. It points to the fact that the MVC rate of force development, from 0 to 50%, investigated is higher during elbow flexion than during knee flexion. Subjects who achieve a higher level of MVC and MRFD during elbow flexion confirm this capability during knee flexion.

The current issue of *Human Movement* also includes results of research into swimming training discussed in a project paper "Adaptation process in the swimming initiation: the LEARNING TO SWIM Project" and a study on training loads applied in pre-competition training. The authors of the latter have noted that the final stage of preparation before competition features a reduced volume of intense exercises, dominated by exercises from the group of special conditions, which take into account individual adaptive capabilities in the ensuing recuperation processes from among subsequent training units.

The last article in the volume "Bernstein's model of movements construction and contemporary motor control and motor learning theories" is aimed at enhancement of debate on regulatory mechanisms in the process of motor learning.

On behalf of the Editorial Board I would like to express my conviction that the articles included in the present volume of *Human Movement* will become important contributions to the state of physical culture sciences and will inspire many researchers to carry out their further studies. The publication of this volume would not have been possible if it had not been for our Reviewers. I would like to express my deep gratitude to our Reviewers whose in-depth reviews of articles from the two 2007 volumes have made publication of our journal possible.

HUMAN MOVEMENT
2007, vol. 8 (2), 80–88

RELATIONSHIPS BETWEEN PHYSICAL FITNESS AND PERSONALITY TRAITS IN ADOLESCENTS[1]

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ABSTRACT
Purpose. The aim of the study was to determine the relationships between physical fitness and selected personality traits in adolescents, as well as their gender-related diversification. Personality traits determining the level of physical fitness were also examined. **Basic procedures**. The number of participants ranged from 414 to 515 high-school students (depending on the questionnaire) aged 15–17. The standard questionnaires for assessment of psychological variables (FCB-TI, NEO-FFI, HSPQ) and the International Physical Fitness Test (IPFT) were used. **Main findings.** Temperament and personality traits were relatively poorly correlated with the adolescents' physical fitness. The correlations were different in boys and girls. In boys significant correlations were more numerous and physical fitness indices were correlated mainly with temperament and personality, i.e. biologically determined characteristics. In girls fewer relationships limited to environmentally-determined traits were observed. Crystallized intelligence was correlated with the results of all fitness tests, but only in boys. In girls fewer correlations were found. Personality traits enable us to predict adolescents' physical fitness to a very limited extent, and predictors of physical fitness are different in boys and girls. **Conclusions**. The results indicate that boys' psychological traits are mainly related to two pillars of physical fitness ("to be able" and "to know"), while girls' traits to one ("to want").

Key words: physical fitness, personality, temperament, adolescents

Introduction

Relationships between children's and adolescents' physical fitness and personality traits have been a traditional subject of sport psychology for a long time. Recently, however, these relationships have been studied very rarely. The following study aimed to find relationships between physical fitness and personality traits, including temperament traits, using Przewęda's [1, 2] concept of three pillars of physical fitness:
1. to be able to perform a motor task;
2. to know how to perform a motor task;
3. to want to perform a motor task.

The first pillar depends on motor abilities, which are genetically determined and become altered in the process of natural ontogenesis and training. Among the types of motor abilities identified by Raczek [3], coordination skills depend to a great extent on the course of cognitive processes determined by the properties of the nervous system [4]. Coordination abilities are supposed to be strongly correlated with one's personality traits, and in particular with temperament. Motor abilities and personality traits can share the same biological determinants.

Fitness (energy-related) abilities such as endurance or strength depend, first of all, on somatic traits and energy-related mechanisms and should not be strongly correlated with personality traits, as confirmed by some earlier studies [5]. Moderate correlations can be expected in the case of complex abilities (speed, agility), which equally depend on personality and biological traits [4]. Some earlier studies pointed to quite numerous correlations between results of speed and agility tests and personality traits, especially in boys [6].

The second pillar of physical fitness comprises knowledge and motor skills acquired in the learning process. One of the most important factors determining the effectiveness of learning, including motor learning, is fluid intelligence. It can be expected that more intelligent individuals will develop their motor habits faster and easier, and in consequence, will score higher in fitness tests. Individuals with higher intellectual potential

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[1] Research financed by the University School of Physical Education in Warsaw (subject IV-81)

are more knowledgeable in fields other than motor activity, and thus display a higher level of crystallized intelligence. Significant correlations between physical fitness and intelligence, both fluid and crystallized, were confirmed in our earlier studies [6]. Seeking correlations between physical fitness and personality traits can be validated by the fact that such traits as introversion, mental strength and strong ego are conducive to improvement of the motor learning process [7].

Additionally, physically active individuals have more opportunities to develop motor skills, and personality traits are significant determinants of the activity level. The indices of adolescents' motor activity are correlated with their temperament traits (positively with activity, endurance) and personality traits (positively with extraversion, negatively with agreeableness). Agreeableness and extraversion are, respectively, negative and positive predictors of motor activity of high-school students [8]. The extroverts reveal a higher level of energy, they are more physically active, and their activeness allows them to compensate for their initially low stimulation [9]. Conscientious individuals are dutiful, hard-working and responsible. These features are conducive to undertaking motor activity [9]. Conscientiousness and neuroticism are, respectively, positive and negative predictors of students' motor activity [10]. The significance of personality traits can vary, depending on gender. In men the predictors of motor activity were extraversion and conscientiousness, whereas in women it was neuroticism [11]. The relationship between adolescents' motor activity and physical fitness [8] can be expected to yield correlations between personality traits and fitness test results.

The third pillar of physical fitness is motivation. Przewęda and Dobosz [2] mention free will and persistence as decisive features in one's engagement in motor activity. The existence of correlations between results of fitness tests and such personality traits as conscientiousness, super ego strength and willpower was confirmed by earlier studies [5, 6].

The aim of this study was to determine relationships between selected personality traits and physical fitness. The following research questions were formulated:

1. What are the correlations between temperament and personality traits and physical fitness in adolescents?
2. Are these correlations gender-related?
3. What personality traits can be predictors of the students' level of physical fitness?

Material and methods

The following standard research tools were used in the study:

1. B. Zawadzki and J. Strelau's Formal Characteristics of Behavior – Temperament Inventory (FCB-TI) [12];
2. Costa and McCrae's NEO Five-Factor Inventory (NEO-FFI) [13];
3. R.B. Cattell's High School Personality Questionnaire (HSPQ) for assessment of personality of adolescents aged 12–18 [6].

The subjects' physical fitness was evaluated with the use of the International Physical Fitness Test (IPFT). Depending on the research tools used, 414 (HSPQ) to 515 (NEO-FFI) high-school students aged 15–17 were examined. The nationwide study was carried out between 2003–2005 in Poland among selected middle-school grades. According to procedure, the examination of physical fitness took place during P.E. classes at school in May and June as the run tests required proper atmospheric conditions. The diagnosis of personality traits was made during a single advisory class, every two weeks, with the aid of the questionnaires in the following order (one questionnaire per class): (1) Formal Characteristics of Behavior – Temperament Inventory (FCB-TI); (2) NEO Five-Factor Inventory (NEO-FFI); (3) High School Personality Questionnaire (HSPQ). The differences in the number of subjects taking part in individual questionnaire surveys are due to students' absences from school during the examination and the fact that the NEO-FFI was not used among third-grade students.

Results

Temperament traits and physical fitness

The FCB-TI survey was carried out among 455 students, including 213 boys and 242 girls. Tab. 1 presents coefficients of correlation between the subjects' temperament traits and fitness test results. In the group of boys most strongly correlated with physical fitness is emotional reactivity. A high level of reactivity corresponds to low results in six fitness tests and, consequently, low results of general physical fitness.

The boys' physical fitness is also correlated with activity understood as a temperament trait. The greater the boys' activity, the better their results in distance and shuttle run, grip strength tests as well as the higher their total physical fitness score. The other correlations were isolated. The grip strength test revealed most numerous correlations with temperament traits.

In the group of girls only four correlations were significant. Sensory sensivity was positively correlated with the grip strength test results, and negatively correlated with the 800-m run. High briskness is accompanied by high shuttle-run results; while a high level of perseverance is correlated with high sit-up results. It is the opposite in the group of boys.

In the regression analysis two significant negative predictors of physical fitness in the entire sample were identified: emotional reactivity (β = –0.216, t = –4.458, p = 0.000) and briskness (β = –0.104, t = –2.144, p = 0.033). This model explains merely 4% of the variability in physical fitness (R^2 = 0.040, F = 10.327, p = 0.000).

The two negative predicators mentioned above can be noted in the group of boys (emotional reactivity: β = –0.229, t = –3.244, p = 0.001; briskness: β = –0.175, t = –2.586, p = 0.010); the third, positive predictor is activity (β = 0.155, t = –2.270, p = 0.024). This model explains merely 10% of the variability of physical fitness (R^2 = 0.092, F = 8.081, p = 0.000). In the group of girls the regression analysis failed to produce any significant, positive predictor of physical fitness.

The Big Five personality traits (Five-Factor Inventory) and physical fitness

The study with the use of NEO Five-Factor Inventory was carried out in the groups of 213 boys and 302 girls aged 15–16 years. Tab. 2 presents statistically significant Pearson's coefficients of correlation between the questionnaire scales and physical fitness test results, separately for boys and girls. Due to the great quantitative discrepancy between both groups, statistically significant coefficients of correlation differed considerably.

The correlations between the Big Five personality traits and motor traits vary depending on subjects' sex. Many more statistically significant correlations can be observed in the group of boys. A personality trait which is most strongly correlated with the results of fitness tests is neuroticism. It is negatively correlated with the results of five fitness tests and the total physical fitness score. None of these correlations reached the level of statistical significance in the group of girls.

In boys, extraversion is positively correlated with the results of four fitness tests and the total score. These correlations are, however, positive only in the group of boys.

The higher the level of agreeableness in boys, the better their agility, trunk muscle strength and suppleness; the last two are also correlated with conscientiousness. None of these correlations was noted in the group of girls.

The girls in the study featured correlations absent in the group of boys. High grip strength was correlated positively with high agreeableness and openness to experience, and good pull-up test results with high conscientiousness. The higher agreeableness of the girls, the worse their distance run results (800 m).

The analysis of the coefficients of correlation in the group of boys shows three correlations between personality traits and the sit-up test results measuring trunk muscle strength and agility. In girls the grip strength test results were correlated with two personality traits.

The analysis of regression failed to identify any significant predictor of physical fitness measured by the

Table 1. Correlations between temperament traits and physical fitness in boys and girls

Temperament traits	Briskness		Perseverance		Sensory sensivity		Emotional reactivity		Endurance		Activity	
Fitness tests	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
50-m run							–0.192**				0.185**	
Standing long jump			–0.150*				–0.189**					
Distance run 800/1000 m						–0.176**					0.164*	
Grip strength						0.156*	–0.201**		0.174*		0.155*	
Pull-up	–0.143*										0.152*	
Shuttle run 4×10 m	0.154*						–0.172*				0.173*	
Sit-up			–0.182**	0.148*			–0.270**					
Trunk flexion					0.185**		–0.152*					
TOTAL							–0.229**				0.210**	

* p=0.05, ** p=0.01

Table 2. Correlations between personality traits and physical fitness in boys and girls

Personality traits / Fitness tests	Neuroticism		Extraversion		Openness		Agreeableness		Conscientiousness	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
50-m run	–0.165*		0.171*							
Standing long jump	–0.159*		0.167*							
Distance run 800/1000 m								–0.171**		
Grip strength	–0.158*					0.124*		0.169**		
Pull-up										0.121*
Shuttle run 4×10 m			0.247**				0.170*			
Sit-up	–0.195**		0.199**				0.140*		0.142*	
Trunk flexion	–0.192**						0.168*		0.136*	
TOTAL	–0.156*		0.152*							

* p=0.05, ** p=0.01

IPFT among the Big Five personality traits in the entire sample and the group of girls. In the group of boys the only negative predictor of physical fitness was neuroticism (β = –0.156, t = 2.277, p = 0.024). This model, however, explains only 2% of the variability of physical fitness (R^2 = 0.020, F = 5.187, p = 0.024). It can thus be concluded that personality traits do not allow us to predict the level of physical fitness of students aged 15–16 years.

R.B. Cattell's High School Personality Questionnaire (HSPQ) and physical fitness

Tab. 3 presents coefficients of correlation between personality characteristics evaluated by R.B. Cattell's High School Personality Questionnaire, for boys and girls separately. The study using this questionnaire was carried out in the groups of 216 boys and 225 girls aged 15–17 years. The results of the test also varied considerably depending on the subjects' age.

In the group of boys the strongest relationship can be observed between physical fitness and crystallized intelligence which is positively, significantly correlated with all fitness tests and the total physical fitness score. The greatest the subjects' intellectual potential, the better their physical fitness. Sensitivity, high self sentiment (self-esteem) and ergic tension are three personality traits which are correlated with the results of five fitness tests and the total score. Surgency was positively correlated with the results of four tests and, in consequence, with the total score. The remaining personality traits revealed isolated correlations with physical fitness. Two fitness tests, i.e. pull-up and shuttle run, were correlated with the highest number of personality traits (5).

In the group of girls the correlations were definitely less numerous, and at times opposite to the correlations in boys.

The observed correlations between the students' intelligence and physical fitness are validated in the case of endurance and suppleness. In terms of locomotive speed the correlation is reverse: high intelligence score was correlated with low 50-m run results.

Other correlations, regardless of subjects' sex, include a positive correlation between ergic tension and static hand strength and the total score as well as a positive correlation between sensitivity and suppleness and the total score. In girls, unlike in boys, sensitivity was also positively correlated with grip strength. Also in girls emotional stability (ego strength) and guilt proneness were correlated with personality traits. The girls' self-sufficiency is positively correlated with their endurance and suppleness, whereas high self sentiment is negatively correlated with the trunk muscle strength and total fitness. Other correlations were isolated. In the group of girls the distance-run and pull-up tests revealed the largest number of correlations with personality traits (4).

The analysis of regression (Tab. 4) for the entire sample yielded five personality predictors of physical fitness (total IPFT score), which explains only 5% of physical fitness variability. The strongest predictor is high self sentiment, followed by excitability. The other variables (intelligence, sensitivity, surgency) are relatively weak predictors of the students' general physical fitness.

Four of the above mentioned factors (with the exception of excitability) turned out to be significant predictors of the students' physical fitness. The strongest pre-

Table 3. Correlations between personality traits and physical fitness in boys and girls

	50-m run		Standing long jump		Distance run 800/1000 m		Grip strength		Pull-up		Shuttle run 4×10 m	Sit-up		Trunk flexion		TOTAL	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Boys	Girls	Boys	Girls	Boys	Girls
A								0.149*									
B	0.173*	–0.221**	0.204**		0.244**	0.144*	0.136*		0.162*		0.203**	0.250**		0.165*	0.229**	0.253**	
C		–0.150*		–0.158*						0.140*							
D	0.143*					0.169**											0.234**
E																	
F									0.195**		0.222**	0.145*		0.172*		0.170*	
G											0.193**						
H			–0.162*							0.141*							
I			–0.134*		0.245**			0.137*	0.214**		0.232**			0.238**	0.145*	0.174*	
J																	
O						0.155*				–0.200**							0.144*
Q_2						0.241**						–0.161*			0.159*		
Q_3	0.211**				0.185**				0.159*		0.199**		–0.158*	0.177**		0.211**	–0.139*
Q_4	0.179**				0.254**		0.147*	0.153*	0.208**		0.173*					0.231**	0.193**

A – Cyclothymia, B – Crystallized intelligence, C – Ego strength, D – Excitability, E – Dominance, F – Surgency, G – Super ego strength, H – Parasympathetic immunity, I – Sensitivity, J – Individualism, O – Guilt proneness, Q_2 – Self-sufficiency, Q_3 – High self sentiment, Q_4 – Ergic tension, * p=0.05, ** p=0.01

dictor was, however, ergic tension. A high level of physical fitness can be expected from students revealing high ergic tension and self-esteem, who are sensitive, expansive and intelligent. These variables make it possible to predict the boys' physical fitness in about 18%.

In the group of girls the regression equation confirms the significance of high self sentiment, sensitivity, intelligence and ergic tension. However, it should be emphasized that high self sentiment is a negative predictor of physical fitness, which means that a higher level of fitness can be expected from girls with low self sentiment (self-esteem). Another positive predictor is super ego strength. The entire model explains about 8% of the variability of girls' physical fitness.

Discussion

The results of the research point to moderately numerous and relatively weak relationships between selected personality traits and physical fitness in adolescents. In many cases, the coefficients of correlation, although statistically significant due to the large number of trials, failed to exceed 0.2. This can indicate a fairly weak relationship between the variables under study.

The observed correlations are, at the same time, very diverse in regard to subjects' sex. The obtained results produce no conclusions concerning the relationships between personality traits and physical fitness of adolescents in general, but in boys and girls separately. A certain regularity can be noted. A greater number of significant correlations was shown in the group of boys (71 statistically significant coefficients of correlation), and these relationships are more regular, i.e. more frequently a given trait is significantly correlated with results of a few fitness tests. In girls fewer such correlations were observed (only 29), and they are all more isolated. In the case of girls the repeatability is noticed in the fitness tests rather than personality traits, i.e. results of only some tests are correlated with personal traits. This diversification was not observed in earlier research [6].

Table 4. Personality-related predicators of physical fitness

Factors / Group	Entire sample			Boys			Girls		
	β	t	p	β	t	p	β	t	p
Intelligence	0.097	2.258	0.024	0.188	2.927	0.004	0.123	2.287	0.023
High self sentiment	0.126	2.909	0.004	0.205	3.152	0.002	–0.146	–2.624	0.009
Sensitivity	0.090	2.150	0.032	0.196	3.127	0.002	0.123	2.295	0.022
Surgency	0.087	2.049	0.041	0.196	3.125	0.002			
Excitability	0.103	2.435	0.015						
Ergic tension				0.226	3.599	0.000	0.152	2.775	0.006
Super ego strength							0.186	3.316	0.001
R^2, F, p	0.048, 6.463, 0.000			0.181, 10.473, 0.000			0.078, 6.593, 0.000		

The above regularity is particularly visible in relationships between temperament traits and personality traits examined with the aid of NEO-FFI. The test revealed four-to-five times more significant correlations in boys than in girls. Temperament traits, biologically conditioned by the properties of the nervous system, are to a great extent most inheritable and invariable human psychic traits. The Big Five personality traits, neuroticism and extraversion in particular, are also genetically determined, and become only slightly altered in an individual's life. These properties are most strongly correlated with the results of fitness tests achieved by boys.

The identification of correlations gives no information about the direction of correlations. If, however, these correlations concern genetically conditioned personality traits it is possible that:

1. There is a common factor determining both personality traits and the level of physical fitness shown by the test results, or
2. The personality traits discussed determine the students' results of fitness tests only to a very limited extent (considering the obtained coefficients of correlation and results of the regression analysis).

The results of different fitness tests achieved by the boys are negatively correlated with emotional reactivity and neuroticism, and positively correlated with activity and extraversion. Neurotic and emotionally reactive persons react strongly to stimuli, easily generate negative reactions, are emotionally unstable, affected by difficult situations and avoid strong sensations. Due to these two traits individuals unwillingly take up stimulating motor tasks involving physical effort or rivalry [11]. Individuals with such traits have fewer opportunities to develop their motor skills through experience ("to be able" to perform a motor task is one of the three pillars of physical fitness [2]). It is quite the opposite in the case of extroverts, who are highly active in different fields, engage in motor activities more often and have more opportunities to develop their motor skills [9].

However, the fitness test results are also affected by one's motor capacities conditioned by one's fitness and coordination skills. The latter depend to a large extent on the properties of the nervous system.

It should be noted that the discrepancy in the quantity of significant correlations between the HSPQ personality traits is smaller in girls than in boys (36:21). The HSPQ traits include those which are genetically or environmentally determined. It seems that in boys physical fitness is mostly correlated with genetically conditioned traits, whereas in girls with traits developed through the environment and one's own experience. The girls' fitness test results are correlated with such traits as conscientiousness, agreeableness and self-sufficiency. Following this line of reasoning it can be stated that in the case of girls the relationships between physical fitness and personality traits are predominantly associated with the "to want" pillar of physical fitness, which determines one's involvement in motor task performance. Girls with certain personality traits become involved in motor task performance more intensively and are more willing and persistent in executing motor tasks.

The presence of different correlations in the two sex groups can be confirmed by the fact that the girls feature only four relationships with HSPQ personality traits which at the same time can be observed in the group of boys. The application of the other research tools fails to reveal such conformity. Moreover, there are three correlations which are negative or positive, depending on the group of subjects, i.e. correlations between perseverance and the sit-up test results, intelligence and 50-m dash results and high self sentiment and the total fitness score.

Depending on the type of questionnaire used, differences in correlations can also be observed. In the case of temperament and personality traits included in the FCB-TI and NEO-FFI tests, which are to a large extent biologically conditioned, the coefficients of correlation in boys and girls differ significantly. In the case of the HSPQ the differences are far less significant. Cattell's questionnaire has been a controversial tool in the opinion of a number of researchers [14]. Its usefulness in sport sciences was also discussed earlier [15]. The application of the HSPQ in the present study, which examined both genetically and environmentally conditioned personality traits, allowed us to note gender-related differences in correlations between personality traits and physical fitness.

It must also be emphasized that among 25 personality traits under examination only 11 were correlated with the total physical fitness score, and only two traits appear in both sex groups (ergic tension and high self sentiment). Some personality traits within one gender group show negative or positive correlations, depending on the physical fitness test. This can be noted more often in girls (sensory sensitivity, agreeableness, guilt proneness) than in boys (sensitivity). Depending on a motor task, correlations between the test results and personality traits can differ significantly. This can be a proof of usefulness of studies using different physical fitness indices.

Among the physical fitness tests carried out in the group of boys the most correlated with personality traits is the shuttle-run test (11 significant correlations) indicating the level of agility, understood as the ability to swiftly move from place to place and change movement directions [2]. This motor skill is to some extent conditioned by the properties of the nervous system (the speed of transfer of nervous impulses), thus one can discern certain common determinants for personality traits and motor abilities [3].

The second most correlated test is the sit-up test (9 significant correlations). Its result can be considered an index of agility, however, also conditioned by the strength of trunk muscle and – to some extent – by endurance. These correlations are, therefore, more complex. The same number of correlations was revealed in the case of trunk flexion test, constituting an index of spinal suppleness.

In the group of boys the other physical fitness tests reveal from 5 to 8 significant correlations with personality traits (5 in the case of distance run). Physical education experts [2] point to the fact that a long-distance run test is more indicative of the runner's motivation, ambition and strong will than his or her physical fitness. The results of the distance run test are the least correlated with personality traits in boys. In the group of girls, however, the results of this test are correlated with the largest number (6) of personality traits. This indicates that these correlations in girls are associated, first and foremost, with the "to want" pillar, whereas in boys with the "to be able" pillar of physical fitness. The second most correlated physical test in girls, i.e. hand grip strength, does not contradict the above observation either. It might be expected that the strength grip test would be a more reliable index of strength in boys, especially those strongly motivated to show their physical capabilities, than in girls, where the test result most likely depends on their temporary motivation than physical capabilities.

Other physical fitness tests in the group of girls reveal less numerous correlations with personality traits. There are no correlations for the shuttle-run test (otherwise most strongly correlated with personality traits in boys), and there is only one correlation with the standing long jump test. According to some authors [2] the latter depends largely on the strength of legs, i.e. it is mostly determined by innate motor abilities rather than acquired motor skills.

A comprehensive analysis of all multiple, complex correlations would exceed the scope of the present paper. One of the most interesting cases is the correlation between physical fitness and intelligence. Scale B of the HSPQ is used for diagnosis of the level of crystallized intelligence understood as the level of knowledge acquired through experience. The scale results are positively correlated with the results of all fitness tests, but only in boys. The boys' high level of crystallized intelligence is related to high physical fitness level, especially in the sit-up and distance run tests. In girls only three significant correlations can be noted. High crystallized intelligence is correlated with low locomotive speed, but with high suppleness and endurance. In both sex groups crystallized intelligence is a positive predictor of physical fitness. A higher level of physical fitness can be expected in boys with a high level of knowledge through individual experience. As was mentioned above, these correlations could result from the dependence of crystallized intelligence and learning effectiveness on one's individual potential. It should be emphasized that the earlier studies revealed less numerous and sometimes opposite correlations between physical fitness and intelligence, especially among boys [6].

A personality trait featuring different correlations with physical fitness, depending on the subjects' gender is high self sentiment. In boys high self sentiment is positively correlated with the results of five fitness tests and the total score of physical fitness, and is a positive predictor of physical fitness. In girls these correlations are negative and high self sentiment is a negative predictor. The boys' level of physical fitness is correlated with their higher self sentiment, and in the case of girls with their lower self sentiment. This difference can be interpreted as conforming to the gender stereotype as physical fitness is a significant feature of the male stereotype [16]. The conformity of the observed traits with the stereotype may lead to higher self-esteem and self-satisfaction. Gender stereotypes are formed at pre-school age and then, gradually, exert an impact on the perception of oneself and others. They become particularly important at adolescent age when teenagers seek answers to the questions "Who am I?" and "What am I?". Noticing traits constituting the stereotype of the opposite sex in oneself can, in turn, lead to lower self-esteem, and this may be the case with the girls under study.

The correlations discussed above were not found in the earlier research [6], in which high self sentiment was not correlated with any of the physical fitness tests in boys, and was positively correlated with the test results in girls. Both studies differed in the number of tests and subjects' age. A far greater number of subjects took part in the present research, thus its results can be considered to be more representative. The subjects' age is also an important factor. The significance of gender stereotypes increases with age and during adolescence the stereotypes can play a much more significant role than at earlier age.

Both genders feature positive correlations between physical fitness and ergic tension – a positive predictor of physical fitness in both sex groups. Ergic tension refers to the level of psychosomatic tension (irritability of the autonomic nervous system). Subjects with a high level of ergic tension are often irritated and anxious. For them motor activity can be a way to relieve this increased tension; and increased motor activity creates more opportunities for development of physical fitness. Similar correlations were observed earlier, but only in girls [6].

In the light of psychological knowledge, the positive correlations between agreeableness and the results of three physical fitness tests in boys seem surprising. Compromising individuals are usually more disposed towards cooperation than rivalry. It appears, however, that competitive tendencies, which should increase students' motivation during performance of physical fitness tests, reveal the subjects' full capacities, enhance achievement of the best results possible and determine the third pillar of physical fitness, i.e. "to want." These assumptions are confirmed by the results of the earlier research showing physical fitness positively correlated with the tendency to dominate over the physical and social environment [6].

Agreeableness was also a negative predictor of motor activity in adolescents [8], which indicates that higher motor activity conditioning skill development ("to be able") can be expected from less compromising individuals. This, however, requires further research.

The results of the present research point to a small number of significant correlations of endurance and briskness. What is interesting is the fact that endurance, understood as "an ability to respond appropriately in situations requiring long-lasting activity [12, p. 62], is not correlated with the results of the long-distance run test, which seem to be conditioned to a great extent by an individual's personality traits [2]. In the earlier research, endurance, as a temperament trait, was correlated with the pull-up test results. In the present study, it is correlated with the grip strength test (boys only), thus it appears to be more muscle strength-related.

Following Raczek [3], the results of the present study should produce correlations between briskness – understood as "a tendency to respond swiftly, maintain a high level of activity and to change behaviors smoothly [12, p. 61] – and shuttle-run and 50-m run tests. The former occurs only in girls, whereas in boys the coefficient of correlation (statistically non-significant) is negative. The latter has not occurred at all. Additionally, briskness is a negative predictor of total physical fitness in the group of boys and in the entire sample.

Conclusions

The results indicate that boys' psychological traits are mainly related to two pillars of physical fitness ("to be able" and "to know"), while girls' to one ("to want"). The question of correlations between personality traits and physical fitness is still an open one and it definitely requires further research.

References

1. Przewęda R., Trześniowski R., Studies of physical fitness of Polish youth in 1989 [in Polish]. AWF, Warszawa 1996.
2. Przewęda R., Dobosz J., Growth and physical fitness of Polish adolescents [in Polish]. AWF, Warszawa 2003.
3. Raczek J., The conception of structuralisation and classification of human motor activity. In: Osiński W. (ed.), Human motor function: structure, variability, conditions [in Polish]. AWF, Poznań 1993, 64–78.
4. Raczek J., Mynarski W., Ljach W., Theoretical and empirical foundations of development and diagnosis of motor co-ordination abilities [in Polish]. AWF, Poznań 1998.
5. Czerwińska R., Rychta T., An attempt to define the relationship between personality and physical fitness in girls [in Polish]. *Kultura Fizyczna*, 1977, 8, 351–356.
6. Rychta T., Guszkowska M., The search for relationships between personality and temperament and the physical fitness of children and adolescents [in Polish]. *Roczniki Naukowe AWF w Warszawie*, 2000, 39, 113–133.
7. Oleśniewicz P., Learning and teaching complex motor skills versus students' personality [in Polish]. *Human Movement,* 2003, 1(7), 60–64.
8. Guszkowska M., Motor activity and the course of stress transaction in youths [in Polish]. AWF, Warszawa 2005.
9. Rhodes R.E., Courneya K.S., Hayduk L.A., Does personality moderate the theory of planned behavior in exercise domain? *J Sport Exerc Psych,* 2002, 24, 120–132.
10. Hagan A.L., Examining the effects of gender and personality on the predictive utility of the theory of planned behavior. *J Sport Exerc Psych,* 2003, 25 (Suppl.), 62–63.
11. Hagan A.L., Hausenblas H.A., Who will exercise? Does personality predict exercise behavior? *J Sport Exerc Psych,* 2002, 24 (Suppl.), 65.
12. Zawadzki B., Strelau J., The Formal Characteristics of Behavior – Temperament Inventory. Manual. [in Polish]. Pracownia Testów Psychologicznych PTP, Warszawa 1997.
13. Zawadzki B., Strelau J., Szczepaniak P., Śliwińska M., NEO – Five Factors Inventory by Costa and McCrae [in Polish]. Pracownia Testów Psychologicznych PTP, Warszawa 1998.
14. Nowakowska M., Critical analysis of R.B. Cattell's research strategy [in Polish]. *Przegląd Psychologiczny*, 1971, 21, 478–500.
15. Rychta T., Psychological diagnosis. In: Ulatowski T. (ed.), Scientific methods in sport [in Polish]. PTNKF, Warszawa 2002, 143–158.
16. Wojciszke B., A man among men. An outline of social psychology [in Polish]. Scholar, Warszawa 2002.

Paper received by the Editors: January 15, 2007.
Paper accepted for publication: August 3, 2007.

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HUMAN MOVEMENT
2007, vol. 8 (2), 89-97

COMPARATIVE ANALYSIS OF THE TEMPERAMENT OF CHESS AND FOOTBALL PLAYERS AGAINST A BACKGROUND OF THE GENERAL POPULATION

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ABSTRACT
Purpose. The goal of our work is to present, against a background of the general population, the temperamental characteristics of chess players and footballers. **Basic procedures.** Included in the research were 88 males, among them 50 footballers and 38 chess players. The intensity of temperament features was determined through the use of the Temperament Questionnaire (TQ) by Strelau on Stawowska methodology. **Main findings.** Both chess and football players obtained substantially higher results than general males in the scope of nerve processes stimulation strength. In the case of restraining strength, the highest results were obtained by the chess players, which substantially differ in the level of this feature from both footballers and males in general. As far as the mobility of nerve processes is concerned, the highest results were obtained by footballers, substantially higher than chess players and the general population. In the scope of the balance of nerve processes the highest results were obtained by footballers, the stimulation process within them dominates upon the restraining process. An opposite situation exists among both chess players and the male population. Within the latter there is a higher domination of the restraining process upon the stimulation process. As regards the kinds of temperament, chess players are distinguished by a great number of phlegmatics, while footballers a great number of cholerics 2. **Conclusions.** Among chess players dominate persons that are balanced with a relatively high level of nerve processes stimulation strength and a much differentiated level of mobility for these processes. However, footballers are also characterized by substantially high levels of nerve processes stimulation as well as their high mobility. Among them there are a lot of balanced persons and those that have a level of stimulation strength that dominates decidedly upon the level of nerve process restraining strength.

Key words: temperament, chess players, footballers, general population, males

Introduction

Interest in temperament reaches back to the ancient times. The first concept of temperament was created by Hippocrates and Galen. They assumed that the differences in psychological functioning between people have similar biological grounds. Despite the fact that they were only speculating, it may be surprising that some of their theories found confirmation in modern scientific experiments [1]. At present, science provides various theories and definitions of the temperament. In Poland, the Regulative Theory of Temperament by Strelau provides the most popular definition of temperament: "... basic, relatively permanent personal traits that refer to the formal characteristics (energetic and temporal) of behaviour and reactions ..." [1, p. 184].

The importance of temperament in sports, and especially, one of its components – reactivity, has often been subject of scientific research. Although scientists are not unanimous about its role, there are some regularities about it that have been defined. Sankowski [2], based on the analysis of data from various studies, says that temperament, in contrast to abilities (including motor and coordination abilities), can only be slightly modified. Thus, Sankowski thinks that selection for some sports disciplines should be based on the temperament traits. Those sports include: swimming, long distance runs, cross-country skiing, road cycling, speed skating, alpinism, parachuting, aeroplane pilotage, speedway or motorcycle racing, ice hockey, rugby, handball, boxing, taekwon-do and wrestling. All of those sports disciplines require low level of reactivity related to low sensitivity and great capability that allows one to function effectively under great physical and psychological strain. At the same time Sankowski says that in gymnasts or sprinters, higher level of reactivity can be com-

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pensated for by excellent feel, differentiation of muscular tones and ability to achieve higher initial velocities. However, many researchers believe that regardless of the practised sport, only persons with low level of reactivity have a chance of achieving success in sports [3, 4]. Despite common recognition of the aforementioned view, Chybik and Żyto-Sitkiewicz [5], who studied volleyball players of MKS-MOS Warszawa, discovered that the line-up was dominated by highly reactive players, who were better trained. The authors, therefore, think that there are no grounds for running selection in sports that is based on temperament traits. However, they stress the necessity for adjusting individual training loads to the temperament type and individual requirement for stimulation. This issue was studied in detail by Wjatkin and Jegorow [6] and Sankowski [7], who presented correlations between learning motor activities and development of locomotor traits in relation to reactivity level, gender, training methods and loads. Coming back to the paper by Chybik and Żyto-Sitkiewicz [5], one should focus on the fact that those authors did not analyse the behaviour of players at the most difficult moments of the game, they did not seek an answer to the question of whether better training of highly reactive players in the club has a reflection in higher success rate in situations of game stress. Zawadzki and Ciota [8], who investigated relation between the level of technical training of wrestlers and their reactivity and sport results, reached a conclusion that in highly reactive wrestlers only perfect training and most probably a specific set of other psychological traits, e.g. high self-esteem and high level of self-composure, can reduce the pre-competition tensions to the level that enables the players to cope with that difficult situation. Unierzyski and Gracz [9] say that there is a strong correlation between the level of sport results of tennis players and the level of the nervous system stimulation (affects the level of reactivity). According to those authors, low reactive players reach the state of optimum stimulation that enables them to function most efficiently only in the event of an important match.

Although knowledge in this field is vast, in practice it is used only to small extent. Coaches are often not aware of the temperament of their players and that is why training loads do not suit players' individual requirements. There are no selection methods in use that take into account players' temperament. It is very probable that players with extensive experience managed to become professional and persevere in practising their disciplines because they have gone through the process of natural selection. Therefore, we have assumed that comparing the temperament of players with extensive experience against general population should reveal certain differences – traits characteristic of sportsmen. Additionally, we should check if the kind sport practised has impact on those characteristics. Such studies have already been conducted, yet they examined the characteristics of behaviour only at the energetic level [10]. For analysis, we have chosen two utterly different groups of players: footballers and chess players.

The aim of this paper was to present, against the background of general population, a comparative characteristic of the temperament of footballers and chess players.

We posed the following questions:
1. Do groups of footballers and chess players differ between one another and from the general population in the intensity of temperament traits?
2. Is the number of persons with particular kinds of temperament equal in the group of footballers, chess players and in general population?

Material and methods

The study included 88 sportsmen with at 8 year-long experience, out of which 50 played football and 38 played chess. The footballers under study were students of Wrocław University School of Physical Education and the chess players were students who took part in the Academic Chess Championship of Poland in 2005. Both groups were compared with the general male population, i.e. persons studied by Stawowska [11], who on the basis of those studies developed sthène measures for the Temperament Questionnaire (TQ) by Strelau [12]. The questionnaire was built according to the assumptions of Pawłow's theory, therefore, one can examine the strength of nervous processes in terms of stimulation (reactivity is its reverse) and inhibition, their mobility and balance. Based on the TQ one can also define the type of temperament according to Stawowska typology [11]. That author believes that mobility and balance of the nervous processes are the basic traits of the nervous system that define a given type of temperament. Depending on the intensity of those traits she isolated the following types of temperament: sanguinic, phlegmatic, choleric 1, choleric 2, mixed choleric 1, mixed choleric 2, melancholic and mixed melancholic.

It should be underlined that there are newer tools for examining temperament according to the modified version of the Regulative Theory of Temperament [1]. They, however, do not allow one to isolate the types of temperament. Moreover, Eliasz [13] believes that the newer versions of the QT are controversial, e.g. The Questionnaire of Regulative Theory of Temperament (QRTT) does not allow us to examine sensory sensitivity, although it is the fundamental trait distinguished by Strelau.

The obtained results were subjected to a statistical analysis. Using Statistica 6.0 software, the researchers performed the Student's t-test for independent samples, calculated the significance of differences between the two mean values and the structural indexes (%). The differences were statistically significant when $p < 0.05$.

Results

As can be seen in Fig. 1, the examined groups of sportsmen obtained higher results than the general population in terms of strength of stimulation of nervous processes. The highest level of that variable was observed in the group of footballers, who however, do not differ significantly from the chess players in that respect. This allows one to say that in terms of strength of nervous processes stimulation, the examined sportsmen belong to the group that has been selected from the general population. Yet, such a view is thoroughly justified, as the results of the footballers are different from the mean results of the general population at the same age. The difference between the chess players and the general population was not statistically significant, however, one can say that it is significant, since $p = 0.06$. This means that the examined groups of sportsmen differ from the general population in terms of higher psychological endurance that is tightly linked with the high level of the nervous processes stimulation.

The data presented in Fig. 2 show that the chess players have highest inhibition of the nervous processes. They show a significantly higher level of this trait than the general population and footballers. This means that the chess players learn quicker to react to various kinds of social situations connected with restraining or delaying one's actions.

Footballers had the highest results in terms of mobility of nervous processes whereas the chess players had the lowest results (Fig. 3). The chess players did not differ significantly from the general population in that re-

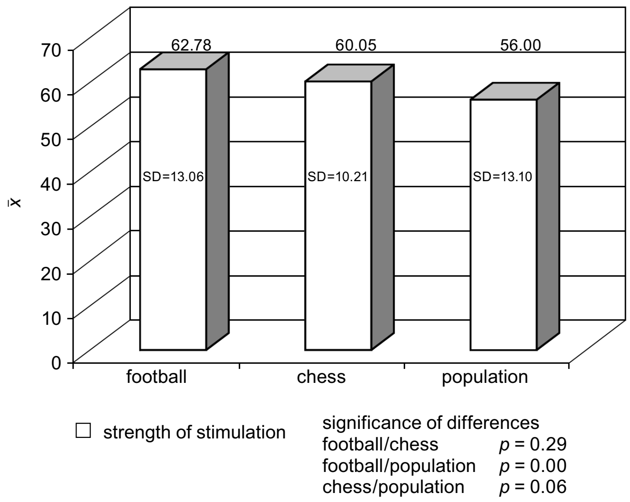

Figure 1. Mean arithmetic values of the stimulation strength in footballers, chess players and the general population (SD – standard deviation)

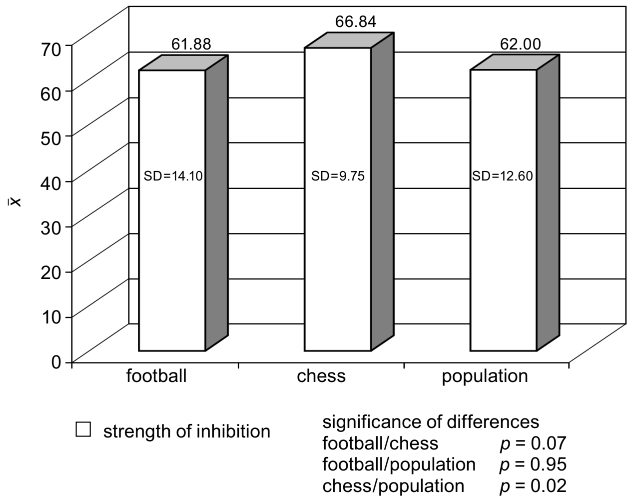

Figure 2. Mean arithmetic values of the inhibition strength in footballers, chess players and the general population (SD – standard deviation)

spect and the footballers stood out. It means that they react rapidly to the stimuli from the environment and their reactions are adequate.

Data presented in Fig. 4 show that footballers had the highest results in terms of balance of nervous processes and they differed significantly from the corresponding groups in that respect. The results above 1.00 mean that the stimulation process dominates over the inhibition process and those players may have problems with resisting an impulsive reaction even when the situation does not require one. Both in the chess players and general population the level of inhibition strength domi-

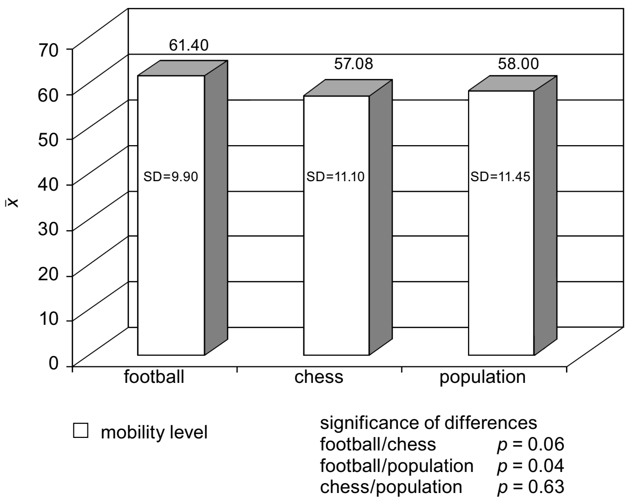

Figure 3. Mean arithmetic values of nervous mobility in footballers, chess players and the general population (SD – standard deviation)

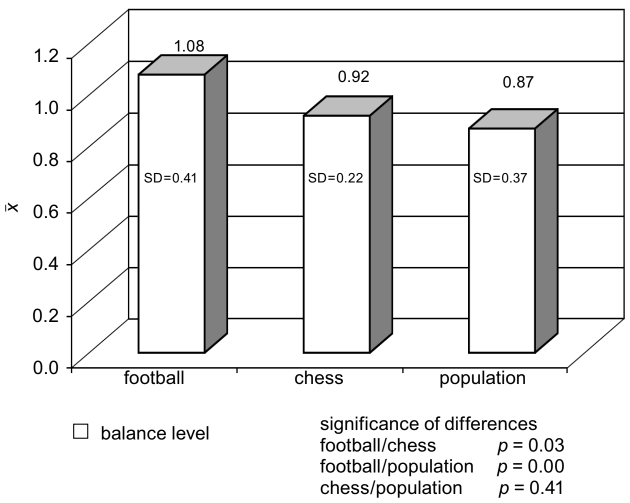

Figure 4. Mean arithmetic values of nervous balance in footballers, chess players and the general population (SD – standard deviation)

nates over the stimulation of the nervous processes. This means that they find it easier to resist impulsive reactions according to requirements of social situations. The domination of the inhibition over stimulation is characteristic of the representatives of the general population, as they are able to restrain from various actions and reactions, even when it is justified by the situation, e.g. they may restrain from an assertive reaction that would be advisable.

Data presented in Fig. 5 show a percent distribution of particular kinds of temperament in Polish population and in footballers and chess players. All of the distinguished groups show the highest percentage of sanguinics with the largest number of those among the chess players and the lowest in the general population. The following most numerous group includes melancholics and mixed melancholics. Among footballers there dominate cholerics 2 and cholerics 1, and phlegmatics among the chess players. Mixed cholerics 1 and 2 are the smallest group among the footballers and the general population and mixed cholerics 1 and cholerics 2 among the chess players.

Tab. 1 shows the significance level of differences between the numbers of the types of temperament in the groups under examination. The footballers differ significantly from the chess players in terms of the number of phlegmatics and cholerics 2. There are more phlegmatics among the chess players and more cholerics 2 among the footballers. Comparing the footballers with the general population, one can see that there are more cholerics 2 among footballers, whereas the same comparison in chess players shows a higher number of phlegmatics.

Discussion

The studies on the specificity of the psychological traits in sportsmen in particular sports disciplines and in comparison with the general population have been conducted for years. They took into account both the relatively permanent traits of biological origin and those more plastic, developed throughout life. Those studies, however, did not provide unanimous results. Some studies indicated existence of a psychic silhouette of a sportsman, some did not confirm such results [14]. The results presented above belong to the first group of studies, since they show some characteristic differences between the general population and chess players and footballers in the range of traits and types of temperament. Therefore, one can speak about "natural" selection in sports that takes place both at the moment of taking up (or not) sport activity and at the moment of giving up at the initial stage of training. The analysis of the research results of various authors shows that the selection is proportional to the degree of physical danger that is connected with practising a given discipline of sport [15, 16]. That kind of selection is stronger in women [17]. However, taking into consideration high level of safety characteristic of the chess, the phenomenon of selection has had to be connected with other factors e.g. pre-competition stress (additionally we only studied males).

Both chess players and footballers obtained significantly higher results than the general population in

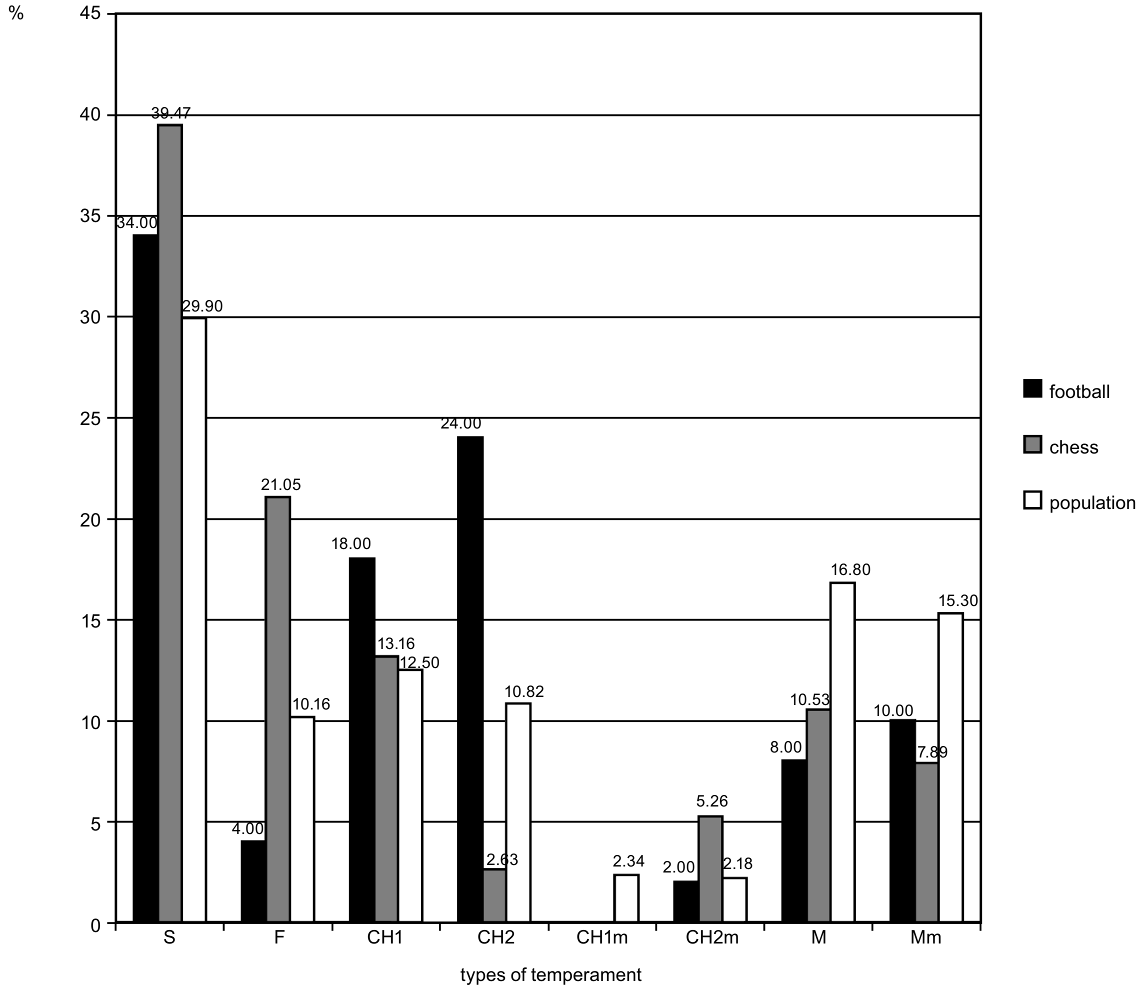

Figure 5. Percent distribution of the individual types of temperament (S – sanguinic, F – phlegmatic, CH1 – choleric 1, CH2 – choleric 2, CH1m – mixed choleric 1, CH2m – mixed choleric 2, M – melancholic, Mm – mixed melancholic) in the examined groups

Table 1. The level of significance of differences between the examined groups in terms of percent distribution of the individual types of temperament (S – sanguinic, F – phlegmatic, CH1 – choleric 1, CH2 – choleric 2, CH1m – mixed choleric 1, CH2m – mixed choleric 2, M – melancholic, Mm – mixed melancholic)

	S	F	CH1	CH2	Ch1m	CH2m	M	Mm
football/chess	0.60	0.01	0.58	0.006	1.00	0.41	0.68	0.73
football/population	0.53	0.15	0.25	0.003	0.27	0.93	0.10	0.30
chess/population	0.20	0.03	0.84	0.110	0.34	0.20	0.30	0.21

terms of the strength of stimulation of nervous processes, which means that those individuals are resistant and efficient. This view is consistent with the assumptions and results obtained by other authors [18–21], according to whom low reactivity is the key to successful sports career. It is connected indispensably with resistance and high demand for stimulation, which allow an individual to undertake the huge psychophysical effort of training and participation in competitions. Therefore, sportsmen are characterized by lower level of reactivity than non-training people [18, 22]. Rychta and Wysocka [20] examined 18 athletes (7 juniors and 11 seniors) whose results on the strength of stimulation of nervous processes were even higher than in the chess players ($\bar{x}$ = 60.05) and footballers ($\bar{x}$ = 62.78), the mean values were as follows; 63.24 for juniors and 64.36 for seniors. Despite the fact that in our studies footballers obtained better results, the difference in reactivity between them and chess players was not statistically significant. Therefore, such distribution of results can be incidental. Then both footballers and the chess players can perform intensely for a long time and will not show any functional disorders. Chess require staying highly focused for even several hours of the match. Only such behaviour can guarantee the final success. Therefore, one can assume that functional capacity of the chess player's nervous system has to be similar to the capacity of endurance sportsmen. One should also remember that practising any kind of sport requires long hours of preparation. Effective training requires long-term exercise of mind in the case of chess players and the body in the case of footballers. Both of them would not be possible without adequate level of the stimulation strength. Low reactivity is linked with high psychological endurance. The results of our studies suggest that chess require similar level of stimulation of nervous processes as football and most probably as other sports disciplines. It also corresponds with the results of the leading Polish scrablists. Those of them who lead in the ranking are characterized with lower emotional reactivity than the players with worse results [23]. The level of stimulation of nervous processes turned out to be significant from the perspective of the model champion of modern fencing [24]. Moreover, other studies of footballers showed that the low level of reactivity and high level of endurance determine champion performance [25].

The chess players obtained a significantly higher results than the general population in terms of inhibition of the nervous processes. The footballers we examined did not differ from the general population in that respect. This is not consistent with Sankowski's findings [18]. He examined basketball, football, handball and volleyball players. The first two groups obtained high results and differed from the general population in terms of inhibition strength. Perhaps, the requirements footballers have to meet have changed since that time. Perhaps, as the author himself suggests, the sample he examined was too small to draw any definite conclusions. The level of inhibition decides about the easiness of learning various reactions of resisting or delaying impulsive actions, in accordance with commonly recognized social standards and requirements of the situation. On the other hand, balance of nervous processes, which is the ratio of stimulation to inhibition will be linked to the behaviour of a person in a given situation. Taking into consideration both of those facts, it turns out that footballers differ significantly from the chess players as well as from the general population, they show dominance of the stimulation over the inhibition. This means that the chess players learn the reaction of inhibition quicker, simultaneously it is easier for them to restrain impulsive reactions in a specific situation. The level of inhibition and balance of the nervous processes, so far have not been analysed from the perspective high-performance sports. There are data showing that in contact sports, the level of stimulation dominates over the level of inhibition. Opposite results are achieved by representatives of other disciplines, which can include football and chess [26]. Such were the findings of Sankowski [18], however, they were not confirmed by Pietraszewski's [22] findings on handball players and other findings on highly qualified fencers [24]. Neither did our findings confirm this correlation, at least in the case of footballers. Perhaps, the division of sports disciplines presented in the paper of Marks and Romanowska-Tołłoczko [26] was not detailed enough. It is also possible that this is a result of continuous changes in sport. Regarding our studies and the difference in the balance of nervous processes between chess players and footballers, it may result from the specificity of a given sport discipline. Game of chess requires piece of mind and composure, the game room has to be quiet and regulations enforce various types of behaviour (for example one cannot strike the clock even when they are nervous and have to make rapid movements, one also has to make a move when they touch a pawn). A chess player who could not control impulsive, emotional reactions would, e.g. comment their opponent moves aloud, laugh, shout or curse, when they noticed that through lack of complete focus they have just wasted several hours of effort; have difficulties with resisting giving hints to players from the neighbouring table. Inability to learn various reactions of resisting would lead to continuous admonitions and to a loss of a point or ultimately to disqualification from a tournament. The existing football regulations do not enforce such high self-control as in the case of chess players. Additionally, in classical chess game it is very important to think over every move one wants to make, create a plan and carry it out. All of those actions are easier to perform for a person with high level of inhibition. A person who does not possess that trait, when they see a move that in their judgement would ensure success, would make that move without due consideration. In majority of situations this would bring defeat to that person. Instructors often repeat the following sentence to young players: "think with your head not your hand", which perfectly shows the necessity of restraining from impulsive actions. In football, an over-impulsive reaction carries a risk of getting a yellow or red card by a player. At the same time, the players are taught various aggressive reactions (e.g. purposeful fouls) aimed at bringing measurable effects [27]. For a person with large dominance of inhibition over stimulation it may be difficult or even impossible to breach commonly acknowledged social standards.

Our studies show that footballers are characterized by higher level of mobility of nervous processes than the chess players and the general population. The reason for that may be the character of the discipline – football requires high locomotor activity, dynamism and rapid responses to the ever changing situation on the pitch. High level of mobility of nervous processes is one of the traits of temperament that determine success in that discipline of sport [19], as it results in quicker learning of complex locomotor activities and is very important for good football training. Some authors advise that phlegmatic people (of low mobility level) should not be eliminated from high performance sports too early, as they learn complex locomotor activities slower at the start, but they speed up as they proceed. On the other hand, people of high level of mobility learn a habit rapidly when it is introduced, but may have problems with bringing it to perfection later on. Gracz and Sankowski [29] say that in people with low mobility level attention should be paid to increasing speed and dynamism of motion. This, according to them, is important especially at the initial stage of training, when the body is most flexible and the speed growth rate is the highest. Apparently, the game of chess does not require such high level of nervous mobility, yet it would be useful when a player is short of time in a timed game or playing rapid chess. However, these are only selected elements of that discipline of sport and they are not the most important ones. Low level of mobility may also bring success in other disciplines of sport. Following Wjatkin [28], junior rowers have problems with maintaining steady pace throughout the distance, therefore the coxswain or pace keeper is always a person with low mobility of nervous processes, who finds this task easy to perform. This solution is 100% effective among the most successful junior rowing crews. In senior rowers, however, more emphasis is put on tactical manoeuvres that require changing rowing rhythm and higher level of nervous mobility. Sankowski [18] shows that among team sports, handball and basketball players are characterized by the highest mobility. A high level of this trait is also characteristic of the leading fencers [24] and grass hockey representation [30].

Our studies have shown that there are far more phlegmatics among the chess players than among footballers and general population. This is a balanced and slow type of a person. Taking into consideration that majority of chess players are sanguinics (compared to the footballers and general population), i.e. balanced persons with high level of mobility, one can assume that this discipline requires balance between the level of stimulation and inhibition, whereas the level of mobility is of secondary significance. Following the results of Stawowska [11], the highest efficiency of mental processes is characteristic of sanguinics and cholerics 1, cholerics 2 are slightly less efficient, phlegmatics and mixed melancholics are in the middle of the rank and melancholics are least efficient. Different order of percent shares of particular types of temperament among chess players may result from the fact that the activity performed by the persons examined by Stawowska can be perceived as easier than a chess game, since it was adding up columns of five two-digit numbers. Moreover, this activity lasted 80 minutes, whereas, a classical game of chess can last even up to 6 hours.

Football players dominate over the chess players and the general population in terms of the number of cholerics 2. In those people the level of stimulation significantly dominates over the level of inhibition, while mobility is at least average. We assume that this type of temperament is one of the dominant types among footballers, as top-class players in this discipline, apart from talent and high level of training, have to possess certain personal traits, such as self-confidence, dynamism, initiative, strong will, sense of engagement in work and training, in order to achieve success. Such a high number of cholerics 2 among footballers explains high number of yellow and red cards received. Regulations require far greater self-control from the chess players.

Both in footballer and chess players in comparison to the general population, there are less melancholics and mixed melancholics. Those are not statistically significant differences, however, regarding the number of melancholics, footballers differ significantly from the general population. It is not surprising then that Blecharz and Fiedor [19] claim that this type of temperament gives the lowest predispositions for achieving success in sports. The share of individual types of temperament among volleyball players examined by those authors differs from both footballers and chess players examined in our studies. That research population consisted of: 26.09% of sanguinics, 8.70% of phlegmatics, 13.04% of cholerics, 21.74% of cholerics 2, 0% of mixed cholerics 1, 13.04% mixed cholerics 2, 13.04% of melancholics and 4.35% mixed melancholics (compare Fig. 5). Relatively small number of phlegmatics and a high percent of cholerics 2 indicates a greater similarity of this group to footballers rather than to the chess players. Sankowski [18] also obtained different results regarding the percent distribution of individual temperament types. Although he used a completely different qualification procedure, still the very low number of cholerics among the examined footballers and relatively high number of phlegmatics in comparison to our findings is intriguing. Perhaps it is only a matter of typology in use; perhaps it is a matter of the differences between football today and 25 years ago.

Conclusions

Footballers and chess players do not differ significantly regarding the level of nervous processes stimulation. Both groups, however, differ significantly in that respect from the general male population at similar age.

The chess players do not differ significantly from footballers in terms of the level of inhibition of nervous processes, yet that difference is large enough so that we can speak about a tendency of achieving higher results by the chess players. In this regard, they obtained significantly higher results than the general male population.

Chess players and footballers differ significantly in terms of balance of nervous processes. Persons playing chess are characterized by the dominance of inhibition over stimulation; in footballers the situation is reverse. Footballers differ significantly in this regard from the general population, who are characterized by dominance of inhibition over stimulation that is even higher than in the chess players.

Footballers are characterized by a higher level of mobility than the chess players. Despite that this difference did not reach the assumed level of statistical significance, still it is large enough to describe it as a tendency towards differentiation between the examined groups of sportsmen. Footballers achieved significantly higher results than the general male population in this regard.

There are significantly more cholerics 2 among the footballers than in the chess players and the general male population. Whereas, in the chess players there are significantly more phlegmatics than in both groups compared.

References

1. Strelau J., Psychology of temperament [in Polish]. PWN, Warszawa 2002.
2. Sankowski T., Psychological aspects of selection and recruitment in sport [in Polish]. *Kultura Fizyczna*, 2002, 7–8, 2–6.
3. Birjukowa Z.I., Sportsmen higher nervous system [in Russian]. Fizkultura i Sport, Moskwa 1961.
4. Rodinow A.B., The psychology of sport ability [in Russian]. Fizkultura i Sport, Moskwa 1973.
5. Chybik D., Żyto-Sitkiewicz D., Temperamental determinants of success [in Polish]. *Trening*, 1993, 2, 94–109.
6. Wjatkin B.A., Jegorow J.W., The characterological differences in dynamics forming the motor routine in various forms of activity [in Russian]. *Teoria i Praktyka Fiziczieskoj Kultury*, 1968, 7, 28–31.
7. Sankowski T., Reactivity to stimuli as a determining factor in the pattern of activity in sports. *Studies in Physical Culture and Tourism*, 1998, 5, 57–66.
8. Zawadzki B., Ciota L., Temperamental reactivity and wrestlers technical skills [in Polish]. *Sport Wycz*, 1990, 7–8, 93–99.
9. Unierzyski P., Gracz J., Temperament and achievement motivation – critical permanent psychological factors in tennis. *Studies in Physical Culture and Tourism*, 2002, 9, 125–131.
10. Zawadzki B., Temperament: selection or compensation? In: Tyszka T. (ed.), Psychology and sport [in Polish]. AWF, Warszawa 1991, 85–112.
11. Stawowska L., Different types of personality and human activity [in Polish]. Seria B: *Studia i Monografie WSP w Opolu*, 1977, 52.
12. Strelau J., Temperament, personality, activity [in Polish]. PWN, Warszawa 1985.
13. Eliasz A., Internal and external obstacles in effective stimulation control [in Polish]. *Czasopismo Psychologiczne*, 1995, 1(3), 129–141
14. Kosińska H., Personality of athlete. In: Tyszka T. (ed.), Psychology and sport [in Polish]. AWF, Warszawa 1991, 56–74.
15. Zukerman Z., Sensation seeking and sports. *Personality and Individual Differences*, 1983, 4, 285–292.
16. Babbit T., Rowland G., Franken R., Sensation seeking and participation in aerobic exercise classes. *Personality and Individual Differences*, 1990, 11, 181–183.
17. Gunderssheim J., Sensation seeking in male and female athletics and nonathletics. *International Journal of Sport Psychology*, 1987, 18, 87–99.
18. Sankowski T., Temperament as one of the determinants of choosing particular sport games [in Polish]. *Roczniki Naukowe AWF Poznań*, 1980, 29, 193–199.
19. Blecharz J., Fiedor M., Temperamental determinants of success in sport [in Polish]. *Wychowanie Fizyczne i Sport*, 1983, 3–4, 59–61.
20. Rychta T., Wysocka T., Some changeable personality factors in track and fields sportsmen and sportswomen [in Polish]. *Wychowanie Fizyczne i Sport*, 1988, 1, 107–127.
21. Bielec G., Lipowski M., Temperamental features of effective anticipation results in swimmers [in Polish]. *Rocznik Naukowy AWFiS w Gdańsku*, 2002, 12, 183–188.

22. Pietraszewski P., Psychological diagnosis of young handball players [in Polish]. *Zeszyty Metodyczno-Naukowe AWF Katowice*, 2005, 17, 81–93.
23. Terelak J.F., Nurkiewicz J., Temperament vs. the volitional control in Polish scrabble players [in Polish]. *Kultura Fizyczna*, 2006, 9–12, 53–63.
24. Borysiuk Z., Analysis of changes in saber fencing after the introduction of electrical scoring apparatus. *Hum Mov*, 2005, 6(2), 129–135.
25. Danielik R., Some personal and temperamental features in football players of youth national team [in Polish]. *Trening*, 2000, 2(46), 77–88.
26. Marks M., Romanowska-Tołłoczko A., Psychological differentiation of competitors – students of University of Physical Education – in regard to putting an opponent under type of pressure. In: Wlazło E. (ed.), Students of physical education in psychological and pedagogical opinion [in Polish]. AWF, Wrocław 2001, 59–75.
27. Szmajke A., Doliński D., The other side of the coin: positive and negative psychological effects of sport. In: Tyszka T. (ed.), Psychology and sport [in Polish]. AWF, Warszawa 1991, 202–228.
28. Wjatkin B.A., Temperament in sport activity [in Russian]. Fizkultura i Sport, Moskwa 1978.
29. Gracz J., Sankowski T., Sport psychology [in Polish]. AWF, Poznań 1995, 233–258.
30. Tomecka M., Muniowska J., Temperament of field hockey players [in Polish] *Zeszyty Metodyczno-Naukowe AWF Katowice*, 2006, 21, 187–195.

Paper received by the Editors: March 5, 2007.
Paper accepted for publication: October 1, 2007.

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HUMAN MOVEMENT
2007, vol. 8 (2), 98–103

DIFFERENCES IN EXPERIENCING RELAXATION BY SPORT COACHES IN RELATION TO SPORT TYPE AND GENDER

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ABSTRACT
Purpose. Stress and burnout symptoms can adversely affect coaches. Traditionally, attention has been paid to tension problems experienced by athletes, but often it is coaches who are under a greater amount of pressure to succeed than athletes. The goal of the research was to compare two groups of coaches: individual sports coaches and team sports coaches in terms of their reaction to and experience of relaxation exercises. The authors also intended to determine possible differences between male and female coaches. **Basic procedures.** The study was carried out in groups of students (n = 91) involved in relaxation exercises as part of the Coaching Postgraduate Program run by the University School of Physical Education in Wrocław. The students participated in 6 to 12-hour relaxation programs, which mainly consisted of Jacobson's progressive relaxation exercises with selected Schultz' and Yoga Nidra techniques. The Relaxation-Concentration Exercises Questionnaire (RCEQ) was used in the study. **Main findings.** The ANOVA was used in the statistical analysis. As a result, the relaxation level of student coaches of individual sports was found to be significantly higher in comparison with the student coaches of team sports. As far as the subjects' gender was concerned the results also showed that the women student coaches had achieved the highest score amongst all the groups under study, both male and female. **Conclusions.** The coaches of individual sports are better prepared to achieve a deeper state of relaxation. Relaxation techniques can be extremely useful in developing constructive stress management programs in all phases of coaches' work. However, the knowledge of the subject, which can be applied to set up some practical stress management strategies, is still very limited.

Key words: relaxation training, sport coaches, sport, gender

Introduction

The coaching profession, like any other professions, includes stages characterized by intensive stress, reduced level of professional activity, physical exhaustion or fatigue. All these symptoms constitute a syndrome known as professional burnout [1–4]. The direct, underlying cause of burnout is the negative stress and work overload. A study carried out at the University of South Carolina on a group of 295 swimming coaches revealed a correlation between competition and burnout symptoms [5]. Additionally, indirect causes of burnout may include the coach's low social status and underpayment and, in consequence, a necessity to take up extra jobs. Also the "constant struggle" for better work conditions, constant proving of the importance of the coach's role in society and of the usefulness of his or her professional activity can lead to frustration, low self-esteem and feeling of injustice. The coaching profession demands high resistance to stressful situations. Beside the high level of rivalry, one of the most important parts of the coaching profession is high staff rotation and social pressure. A great deal of international research has been devoted to the psychological costs of teacher-trainer profession [6–9] and problems of interpersonal relations concerning the management [1, 10, 11] and athletes [12–14].

The opposite of experiencing stress is, following Benson's term [15], the relaxation response, understood as a natural response to excessive psychophysical stress [16]. Jacobson, the author of progressive training, pointed to a simple relaxation method consisting of alternating tension and relaxation of individual muscles. The aim of the training is to develop the ability to assess improper muscular tension and exercise intentional muscular relaxation, which then can affect one's psyche and emotions [17, 18].

Relaxation techniques are extensively applied in prevention of stress-related emotional and somatic disorders as well as for improving the effectiveness in different spheres of human activity. A number of studies

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show that regular implementation of relaxation techniques can significantly affect one's state of relaxation [18, 19]; it also reduces one's feeling of anxiety and enhances resistance to stress. Everly et al. [19] considered the improvement of inner control and self-esteem to be durable consequences of systematic relaxation. Some studies point to a steady trend to adjust patterns of behaviour for better stress management. In the sport community research has shown the impact of relaxation techniques on the attainment of better results as well as a significant reduction of anxiety and improvement of self-esteem. Another problem is coping with difficult situations and tension by the coaching community. Most studies have focused on sport coaches' burnout, while only very few researchers [20–22] have discussed the effectiveness of stress and tension management methods. The present study discusses the problem of stress management during relaxation sessions experienced by coaches of individual and team sports. The main reason for undertaking this research was a great interest of coaches taking part in postgraduate courses in psychotherapy and relaxation training. The coaches often remarked that complementary inclusion of relaxation techniques into their specialist training programs would greatly enhance the effectiveness of their work. The present study should attract coaches' interest in relaxation techniques and possible application of such techniques in their training programs.

The objective of the study was to compare two groups of coaches: individual sports coaches and team sports coaches in terms of their responses to and experiences of relaxation exercises. Two research questions were formulated:

1. Are there any differences between coaches of individual sports and coaches of team sports in terms of their state of relaxation after relaxation exercises?
2. Are these differences (if any) gender-related?

Material and methods

The research sample consisted of active coaches taking part in postgraduate coaching courses organized by the University School of Physical Education in Wrocław. The subjects were 91 coaches, who graduated from the University School between 1998 and 2001. The subjects' mean age was 33 years. A vast majority of subjects were not active athletes any longer. The groups of subjects compared were uniform in terms of their age and sex. During the course the coaches got acquainted with relaxation techniques which could be used in their work with athletes. Each coach attended introductory classes in relaxation techniques as well as training workshops (6 to 12 hours). By the end of the relaxation training course the participants were asked to fill in the Relaxation-Concentration Exercises Questionnaire (RCEQ) developed by one of the authors of the present study. The questionnaire included seven sets of ten items each. The subjects were to give their answers on a five-point scale: from "I totally disagree" to "I totally agree." The present study analyses only answers to the fourth set concerning the participants' experiences during the last session of relaxation training. The relaxation exercises were characterized as 4.1 generally relaxing; 4.2. similar to other exercises; 4.3. similar to exercises experienced earlier under other circumstances; 4.4. physically relaxing; 4.5. steadying the heart and breathing rhythm; 4.6. harmonizing mind and affecting concentration; 4.7. deeply relaxing the body and mind; 4.8. bringing about inner peace; 4.9. similar to sleeping; and 4.10. bringing about the feeling of harmony with the outside world.

The subjects, who were asked to fill in the questionnaire, usually during the 4^{th} or 5^{th} session, had already participated in the training workshops modeled, to a large degree, on Jacobson's progressive training, and elements of Schulz' autogenic training and Yoga Nidra. The program of a relaxation session comprised four sets of exercises: stretching exercises, breathing exercises, mental concentration exercises and relaxation exercises.

Results

The authors divided the subjects into two groups: coaches of individual sports and coaches of team sports. The groups were then subdivided according to the subjects' sex. The statistical analysis was carried out using Statistica 6.0 software package. Student's t-test for independent variables and post-hoc ANOVA/MANOVA tests were calculated.

The comparison of individual sports coaches and team sports coaches in terms of their proneness to relaxation (Tab. 1) shows the former to have achieved better results in almost all indices. The exceptions are item 4.5 (steadying the heart and breathing rhythm), which was assessed higher by the team sports coaches, and item 4.10 (bringing about the feeling of harmony with the outside world), equally assessed by both groups.

Despite the fact that the individual sports coaches scored higher in almost all indices of relaxation, a statistically significant difference was observed only in perception of the exercises as generally relaxing (item 4.1., Tab. 1) and in the total RCEQ score (4.1–4.10, Tab. 1).

Table 1. Arithmetic means of different indices of proneness to relaxation by coaches of individual and team sports

Item	$\bar{x}$ Individual sports	$\bar{x}$ Team sports	*p*
4.1	3.30	2.93	0.04
4.2	1.66	1.52	0.62
4.3	1.85	1.37	0.09
4.4	3.17	3.00	0.38
4.5	3.09	3.23	0.42
4.6	2.85	2.70	0.48
4.7	2.98	2.82	0.39
4.8	3.30	3.02	0.10
4.9	2.94	2.57	0.15
4.10	2.34	2.34	1.00
Total	27.47	25.52	0.05

As far as the subjects' sex was concerned, the women coaches of individual sports achieved the best results (Fig. 1–4), with the exception of exercises perceived as harmonizing mind and affecting concentration. In the case of item 4.6 the women coaches of team sports scored significantly lower than all other subjects (Fig. 1). They also achieved the worst result in the total RCEQ score (Fig. 5), although differing significantly only from women coaches of individual sports.

As was mentioned earlier, the women coaches of individual sports featured the highest quantity of relaxation indices. In the case of general relaxation (Fig. 2) they obtained the highest score, however, differing significantly only from the men coaches of team sports.

Differences between women coaches of individual sports and the other groups were observed in answers to

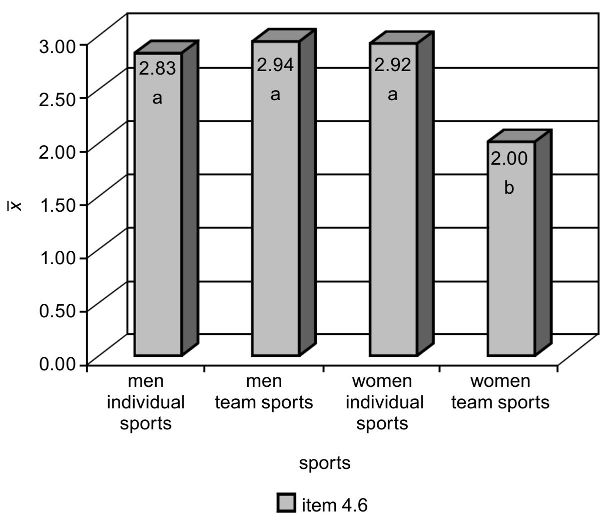

Figure 1. Perception of relaxation as harmonizing mind and affecting concentration by men and women coaches of individual and team sports (arithmetic mean of answers to item 4.6). Different letters on the columns indicate statistically significant differences

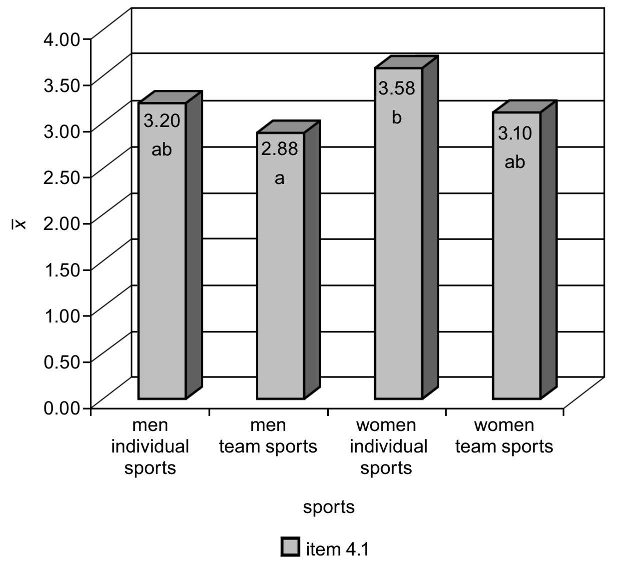

Figure 2. Perception of relaxation training as generally relaxing by men and women coaches of individual and team sports (arithmetic mean of answers to item 4.1). Different letters on the columns indicate statistically significant differences

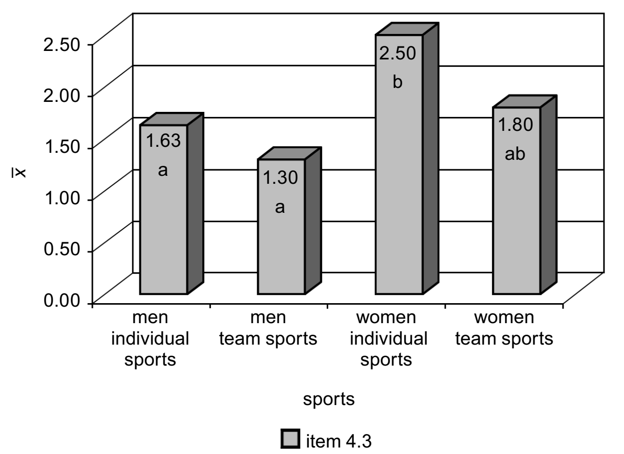

Figure 3. Perception of relaxation training as similar to exercises experienced earlier under other circumstances by men and women coaches of individual and team sports (arithmetic mean of answers to item 4.3). Different letters on the columns indicate statistically significant differences

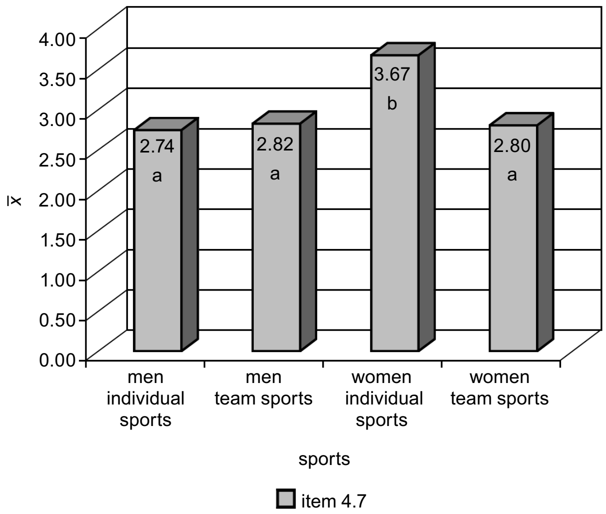

Figure 4. Perception of relaxation as deeply relaxing the body and mind by men and women coaches of individual and team sports (arithmetic mean of answers to item 4.7). Different letters on the columns indicate statistically significant differences

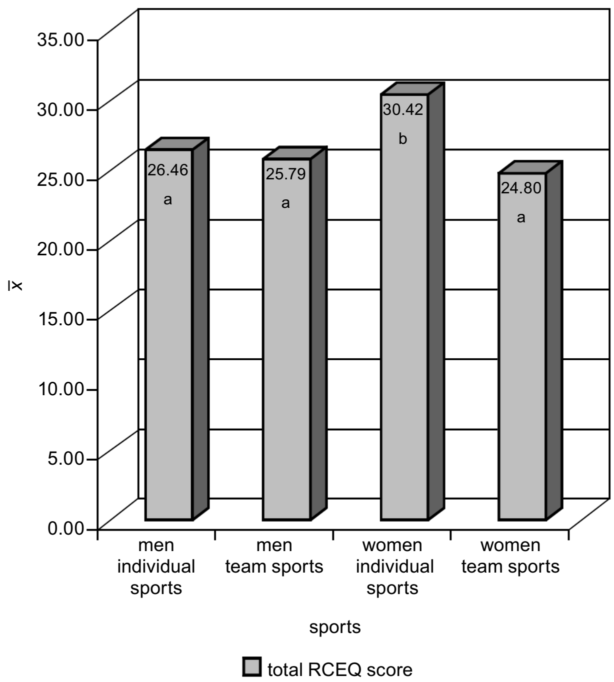

Figure 5. The arithmetic mean of the total RCEQ score by men and women coaches of individual and team sports. Different letters on the columns indicate statistically significant differences

item 4.3. ("similar to exercises experienced earlier under similar circumstances"). These differences were statistically significant in comparison with the two groups of men coaches. Compared to the women coaches of team sports, the individual sports coaches scored higher, but the difference was statistically non-significant.

The women coaches of individual sports differed significantly from all other groups in the perception of relaxation exercises as deeply relaxing the body and mind and in the total RCEQ score (Fig. 4 and 5). These results indicate greater proneness of this group – in comparison with others – to relaxation. It can thus be concluded that proneness to relaxation is related to the type of sport (individual and team sports) as well as the subjects' sex.

Discussion

A number of studies suggest that most stressors affecting athletes also exert an influence on coaches. According to Martin [20], only those coaches can succeed who can effectively manage their own stress and thus become good role models to their athletes. They should be equipped with appropriate strategies which can be applied during important sport competitions but also in the event of their athletes' failures or poor results. Dubos [21] noted that physiological stress experienced by rowing coaches during competition was similar to the stress of their athletes who at the same time expended great physical effort. The analogy between stress reception and the necessity of effective stress management in the competitive period in athletes and trainers alike is obvious. It can be defined as "emotional feedback" or "emotional irradiation" in both groups. The coaches also experience the fear of losing their job, frequent travels and problems with family life.

Scientific publications on psychology of sport have mostly focused on the impact of relaxation on athletes but not on coaches. For example, Hemery [see 22] is his study of 62 Olympic champions showed that 80% of them associated a high sport level with mental exercises including elements of relaxation and imagination training. There is no doubt that stress management or relaxation ability are fairly individual issues. Nowicki [22] emphasizes that relaxation techniques should be selected on an individual basis. Other researchers [19, 22–24] point to the great effectiveness of deep suggestion as a stress management technique in sport. The present study reveals differences in the effectiveness of relaxation training between coaches of individual sports and coaches of team sports. These differences might be explained by the fact that the coaches of individual sports had become familiar with relaxation exercises earlier. It is also possible that these coaches are more disposed towards the reception of internal, individual physical impressions, as opposed to the coaches of team sports more prone to reception of social stimuli. According to Doliński and Szmajke [13] a crucial part of stress management, e.g. during competition, is social support, consisting of feedback received from other people confirming one's membership in a social group and the group's concern about its proper functioning. It is particularly important in conditions of experiencing low self-esteem as it allows for improvement of one's own well-being. Seeking social support is one of the effective stress management strategies mentioned by a number of researchers [24–27]. It can be assumed that both coaches and athletes of team sports have greater possibilities of relieving the tension, and that in the choice of their sports they were motivated by the importance of relations with other people. Witczak's [23] research also points to the fact that mental training can affect muscle relaxation and general relaxation to a different degree in different individuals. His study showed that after five training sessions more than 10% of subjects experienced no results, but about 6% assessed the impact of training as significant and very significant. However, after five weeks of training, only 0.7% still noticed no effects of the training, while for more than 16% the impact was significant and very significant, and for 1.3% tremendously significant. The author carried out his study on a sample of athletes representing twenty different sports.

The results of the present study show that as far as the subjects' sex is concerned, the highest degree of effective relaxation can be observed in women coaches of individual sports and the lowest in women coaches of team sports. In terms of differences in reception of stress in competitive situations, particularly significant are the results of studies [28, 29] confirming the gender-related differences. It is possible that women coaches of team sports pay little attention to inner feelings, concentrating instead on social stimuli. Most likely, their most preferred way of stress management are contacts with other people, which can be justified by their choice of team sports.

Conclusions

Coaches of individual sports achieve higher scores in terms of general relaxation following relaxation training in comparison with coaches of team sports. They also obtain better results in the total relaxation perception score.

As far as the subjects' sex is concerned, it was observed that women coaches of individual sports differed most significantly in the total relaxation score and in perception of deep relaxation of the body and mind from the other groups of subjects. In both cases their results were better than those of other groups.

Women coaches of individual sports achieved better results than the men coaches of both individual and team sports in relaxation perceived as similar to exercises experienced earlier under similar circumstances. They also scored significantly higher than the men coaches of team sports in general relaxation following relaxation exercises.

On the other hand, the women coaches of team sports achieved a significantly worse result than all other groups in relaxation perceived as harmonizing mind and affecting concentration after relaxation training.

The interviews with coaches revealed their expectations to become familiar with theoretical assumptions and practice of stress management as well as relaxation techniques in their training programs. On the one hand, they emphasized the preventive and self-therapeutic advantages of such knowledge, and on the other hand, they pointed to the possibilities of applying relaxation techniques in their work with athletes.

Coaches of individual sports, as opposed to coaches of team sports, face a clear situation of responsibility for their athletes' results. In their work they confront the dilemma of direct, rather than indirect, accountability, more than their team sports counterparts. This can also refer to their early development of stress resistance, already in the competitive period. We can assume that their own sports training in the past and the direct correlation between coaching and the athlete's score are decisive as regards the differences in perception of the state of relaxation observed in the present study.

References

1. Capel S., Psychological and organizational factors related to burnout in athletic trainers. *Athletic Training*, 1986, 21, 322–327.
2. Taylor J., Coaches are people, too: An applied model of stress management for sport coaches. *J Appl Sport Psychol*, 1992, 4, 27–50.
3. Kelley B.C., Gill D.L., An examination of personal/situational variables, stress appraisal, and burnout in collegiate teacher-coaches. *Res Q Exerc Sport*, 1993, 64(1), 94–102.
4. Malec E., Burnout among professionals; reasons and prevention [in Polish]. *Kwartalnik Pedagogiczny*, 2002, 3–4, 267–275.

5. Raedeke T.D., Granzyk T.L., Warren A., Why coaches experience burnout: a commitment perspective. *J Sport Exerc Psychol*, 2000, 22(1), 85–105.
6. Burke R.J., Greenglass E., Work stress, role conflict, social support, and psychological burnout among teachers. *Psychol Rep*, 1993, 73(2), 371–380.
7. Anderson M.B., Iwanicki E.F., Teacher motivation and its relationship to burnout. *Educational Administration Quarterly*, 1984, 20(2), 109–132.
8. Brissie J.S., Hoover-Dempsey K.V., Basser O.C., Individual, situational contributors to teacher burnout. *Journal of Educational Research*, 1988, 82(2), 106–112.
9. Gould D., Dieffenbach K., Overtraining, underrecovery, and burnout in sport. In: Kellmann M. (ed.), Enhancing recovery: Preventing underformance in athletes. Human Kinetics, Champaign 2002, 25–35.
10. Anshel M.H., Kim K.W., Kim B.H., Chang K.J., Eon J.J., A model for coping with stressful events in sport: Theory, application, and future directions. *Int J Sports Psychol*, 2001, 32, 43–75.
11. Blasé J.J., A qualitative analysis of sources of teacher stress: Consequences for performance. *American Educational Research Journal*, 1986, 23(1), 13–40.
12. Nideffer R.M., The Inner Athlete: Mind plus Muscle for Winning. Thomas Y. Crowell Company, New York 1976.
13. Doliński D., Szmajke A., Psychological Reactions for the Starting Situation. In: Tyszka T. (ed.), Psychology and Sport [in Polish]. AWF, Warszawa 1991, 113–152.
14. Kjormo O., Halvari H., Relation of burnout with lack of time for being with significant others, role conflict, cohesion, and self-confidence among Norwegian Olympic athletes. *Percept Mot Skills*. 2002, 94(3 Part 1), 795–804.
15. Benson H., Klipper M.Z., The Relaxation Response, 2nd edition. Avon, New York 1975.
16. Kroll W., Gendersheim J., Stress factors in coaching. *Coaching Science Update*, 1982, 23, 47–49.
17. Jacobson E., Progressive relaxation. *Am J Psychology*, 1987, 100(3–4), 522–537.
18. Kabat-Zinn J., Massion A.O., Kristeller J., Peterson L.G., Fletcher K.E., Pbert L. et al., Effectiveness of a meditation-based stress reduction program in the treatment of anxiety disorders. *Am J Psychiatry*, 1992, 149, 936–943.
19. Everly G.S., Rosenfeld R., Stress, Reasons, Therapy and Autotherapy [in Polish]. PWN, Warszawa 1992.
20. Martin C., Stress Management. In: Morris T., Summers J. (ed.), Sport Psychology. Strategies and Techniques [in Polish]. COS, Warszawa 1998, 77–94.
21. Dubos R., Man and his environment, adaptations [in Polish]. PZWL, Warszawa 1970.
22. Nowicki D., Mental Training. In: Tyszka T. (ed.), Psychology and Sport [in Polish]. AWF, Warszawa 1991, 153–182.
23. Witczak T., Scandinavian Model of Mental Training [in Polish]. *Trening*, 1993, 17(1), 153–167.
24. Berger B.G., Coping With Stress: The Effectiveness of Exercise and Other Techniques. *Quest*, 1994, 46, 100–109.
25. Chang-Liang R., Denney D.R., Applied relaxation as training in self-control. *Journal of Counseling Psychology*, 1976, 23, 183–189.
26. Kulmatycki L., Miedzińska B., Proneness to relaxation and personality traits [in Polish]. *Postępy Rehabilitacji*, 1999, 13(3), 151–159.
27. Bruning N.S., Frew D.R., Effects of exercise, relaxation, and management skills on physiological stress indicators: A field experiment. *J Appl Psychol*, 1987, 72, 515–521.
28. Burke R.J., Greenglass E.R., Sex differences in psychological burnout in teachers. *Psychol Rep*, 1989, 65(1), 55–63.
29. Caccese T.M., Mayerberg C.K., Gender differences in perceived burnout of college coaches. *J Sport Psychol*, 1984, 6, 279–288.

Paper received by the Editors: July 24, 2006.
Paper accepted for publication: August 23, 2007.

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HUMAN MOVEMENT
2007, vol. 8 (2), 104–111

SPATIOTEMPORAL (KINEMATIC) PROPERTIES OF THE FINALISTS OF EUROPEAN SWIMMING CHAMPIONSHIPS IN BUTTERFLY STROKE TRIESTE 2005

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ABSTRACT
Purpose. One of the control methods of swimming practice is a detailed analysis of a swimming race and its component parameters, thanks to which the level of mastery of movement technique can be assessed. The aim of the paper was to specify to what extent spatiotemporal (kinematic) parameters affect the sports result and how these parameters are represented by the best competitors in individual phases of the swimming race. **Basic procedures.** The paper is based on a study of the European Swimming Championships in Trieste, 2005, and analyzes men and women butterfly stroke events at distances of 50 m, 100 m and 200 m. The following spatiotemporal (kinematic) quantities were considered: start time, turning time, swimming velocity, finishing time, stroke rate and stroke length. To specify the differentiation between the analyzed variables, the standardization of results and Pearson linear correlation were used. **Main findings.** It was found that the groups of male and female competitors proved to be fairly diversified in their spatiotemporal (kinematic) quantities. The competition winners when compared with other competitors, featured better average velocity, stroke rate and efficiency. However, no competitor obtained the highest results in all analyzed factors. **Conclusions.** A careful observation of changes of basic swimming technique kinematic parameters and their interpretation enables diagnosis and forecast necessary for proper training development. The knowledge of individual movement technique parameters enables a thorough assessment of the swimmer's training level and makes it possible to match it with model standards.

Key words: swimming, sport result, spatiotemporal (kinematic) parameters at a swimming distance

Introduction

An athlete who competes in top-level sports events should feature a good level of technical, functional, psychomotor and tactical preparation [1–3]. One of the success-determining factors in competitive swimming is the swimmer's level of technical training, consisting of mastery of kinematic parameters and ability to receive kinesthetic-sensory stimuli [4–7]. Two types of kinematic parameters can be identified in swimmers [4, 6, 8, 9]. The first type is the ability to assess and control dynamic and kinematic movement parameters, which is reflected in development of such skills as the sense of developed force, time, pace, rhythm and water. The other type consists of the ability to relax muscles. Mastery of the latter allows synchronizing muscles during swimming [10–12]. A swimmer should, first of all, be able to feel and analyze his/her own movements, create an image of movement of his/her entire body and its individual parts, and adjust movement performance to a given motor task [3, 9, 13]. The level of spatiotemporal parameters, assessed in individual athletes in particular phases of the swimming distance, reveals the swimmer's coordination and technical preparation [5, 9, 14].

Studies of competitive swimming studies point to different methods of men and women swimmers of attaining sports championship. In the assessment of the swimmer's training level a number of tests are applied evaluating the body's functional, psychomotor and technical properties [5, 15, 16]. One of the methods of control of swimming training is detailed analysis of a swimming race, concerned with the race's structure and its constituent parameters. Thanks to such analysis the swimmer's level of technical training can be effectively evaluated [4, 6, 9]. Observation of the swimmer's performance is an important part of the coaching profession, and the coach's conclusions can be crucial for training practice and programming. Video recording of a swimming race can provide information on the swimmer's movement in particular sections of the swimming distance: start, "pure swimming", turns and finish. This information can be invaluable for the coach and the swimmer as it can affect further training strategy, pin-

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point errors and constantly improve the training quality. The data can also be used for comparison of performance of individual parts of the race with the set standards [17, 18]. Thus video recording of spatiotemporal parameters and assessment of their influence on swimming effectiveness is a useful research tool for swimming coaches allowing a complex evaluation of swimmers' training level and optimal execution of particular parts of the swimming race.

The aim

The study aimed at finding a relationship between the level of swimmers' basic kinematic parameters and swimming results at the 2005 European Championships in Trieste in butterfly stroke.

The following research questions were formulated:

1. How do the basic kinematic parameters change and affect the swimming technique at selected sections of the swimming distance: start, turns, finish and "pure swimming" of the swimming event finalists?
2. To what extent can the changes in the basic kinematic parameters affect sports results in butterfly finals at individual swimming distances?

The analysis was also aimed to highlight the finalists' weaker points, which could be then applied in individual programming of swimming training.

Material and methods

The study examined kinematic parameters of men and women finalists at the European Swimming Short Course Championships in Trieste in 2005. The video recording of particular constituent parts of the swimming distance was made by Professor Rein Haljand of the University of Tallinn (Estonia) [19]. The video cameras were installed at designated spots above the water surface and at the bottom of the pool and were connected with electronic measuring devices. The data gathered was then computer-processed and yielded information about the swimmer's speed during the start, swimming, turns and finish. The study analyzed the recording of the men and women butterfly finals at distances of 50 m, 100 m and 200 m.

The parameters under study included: start time (15 m from the starting signal), turning time (7.5 m before and after the turning wall), average swimming time (measured after the start and before the first turn; between turns; after the last turn and before finishing), finishing time (last 5 m time from the swimmer's head to the finishing line), average stroke rate (F_c – stroke cycles per min) and average stroke length (L_c – the distance covered by the swimmer within one stroke cycle). Another parameter was the so-called index of swimming efficiency (W_s) calculated according to the formula:

$$W_s = \frac{L_c \cdot \bar{x}}{100}$$

The stroke rate (F_c) was measured using special electronic devices, from the arm's entry into the water to its recovery. The stroke length (L_c) was calculated according to the formula:

$$L_c = \frac{V_{av} \cdot 60}{F_c} \text{(m)}$$

where:
L_c – average stroke length
V_{av} – average swimming velocity
F_c – stroke rate

In the analysis the differences between the variables were assessed using standardization of results [20] and Pearson coefficient of correlation (r).

Results

Women butterfly 50 m

The difference between the best time (A.K.) (**0:26.05 min**) and the worst time **(0:26.75 min)** at this swimming distance was merely **0.7 s** ($\bar{x}$ – 0:26.42 min, SD – 0.23 s, CV – 0.88). In terms of the spatiotemporal parameters (Fig. 1) the gold medalist achieved the best **start time –** 6.54 s (4.5% better than her competitors' average) and **turning time –** 8.06 s (2.35%). She featured the second highest average stroke rate (F_c) and the 6th average stroke length (L_c). Her average swimming velocity gave her the 5th place, finishing time – 6th place and the W_s index – 3rd place among the race participants.

Men butterfly 50 m

The gold medalist (L.F.) reached the time of **0:23.08 min**, whereas the last time in the final race was **0:23.58 min**, i.e. the difference between the men's times (**0.5 s**) was lower than between the women's times ($\bar{x}$ – 0:23.32 min, SD – 0.19 s, CV – 0.82). The winner of the men's

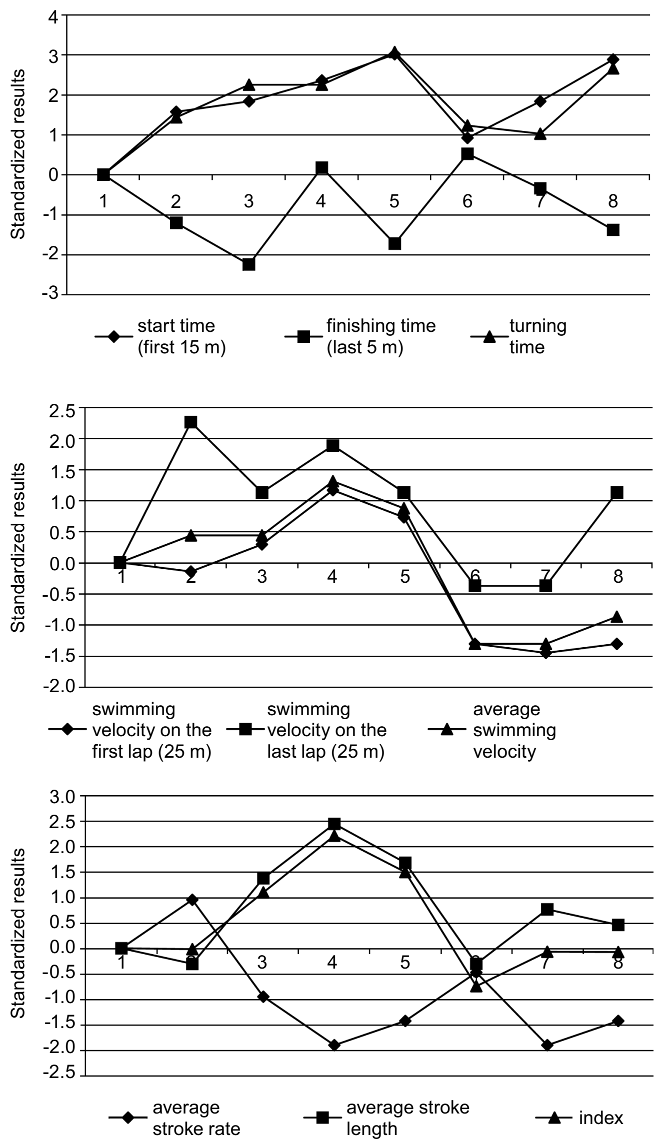

Figure 1. Kinematic parameters at 50 m women

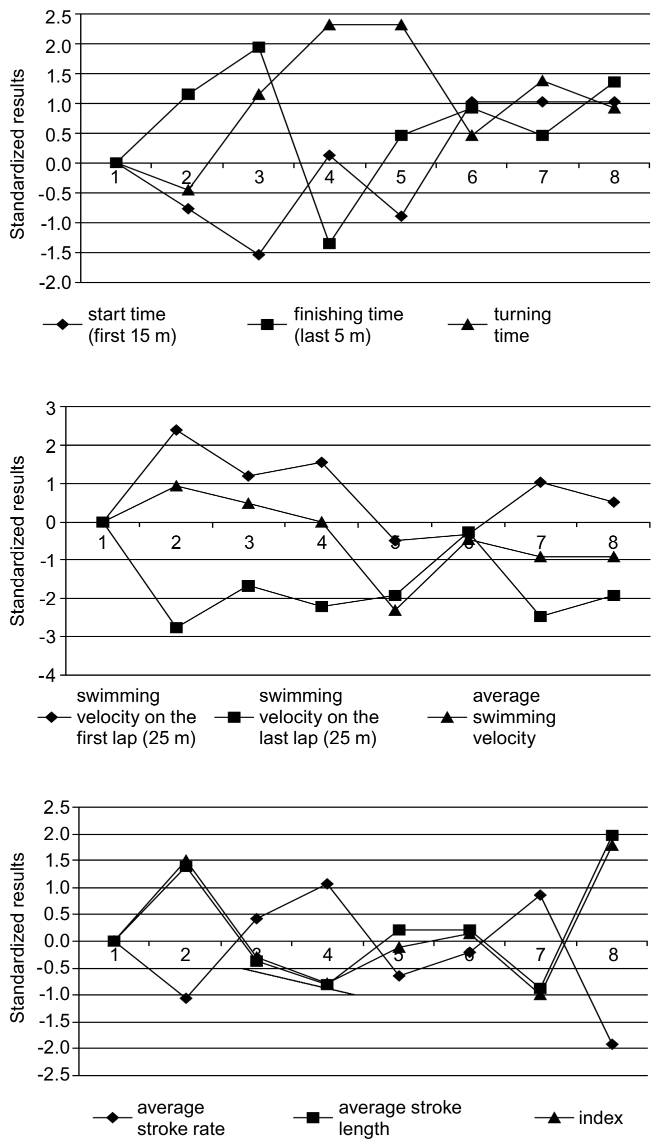

Figure 2. Kinematic parameters at 50 m men

race achieved the best result only in **swimming velocity** (1.97 m/s) in the second lap of the 50 m distance (Fig. 2). It was 3.68% better than his competitors' average speed. The race winner had the 4th stroke rate and the 5th stroke length. He had the second best **turning time** and **finishing time**. He also featured the 4th best W_s index.

Women butterfly 100 m

The winner (M.M.) achieved the time of **0:58.19 min**, while the worst time was **0:59.04 min**, thus the difference between them amounted to **0.85 s** ($\bar{x}$ – 0:58.56 min, SD – 0.29 s, CV – 0.49). She had the best **start time** (7.0 s), i.e. 2.62% better than the others', and **average turning time** (8.61 s; 2.49%) (Fig. 3). She had the 2nd–3rd finishing time, but was only 6th in average swimming velocity, stroke rate (F_c), stroke length and the W_s index.

Men butterfly 100 m

The winner of the 100 m race (T.R.) attained the time of **0:50.55 min,** whereas the last finalist **0:52.22 min**; the difference between them was **1.67 s** ($\bar{x}$ – 0:51.64 min, SD – 0.56 s, CV – 1.08). The winner achieved the best **swimming velocity** on **the final lap** (1.77 m/s), which was 3.5% better than the others', **average swimming velocity** over the entire distance (1.87 m/s; 3.5%), and **average stroke rate (F_c)** – 61 (9.26% better than the other finalists' average). He was only the 6th in

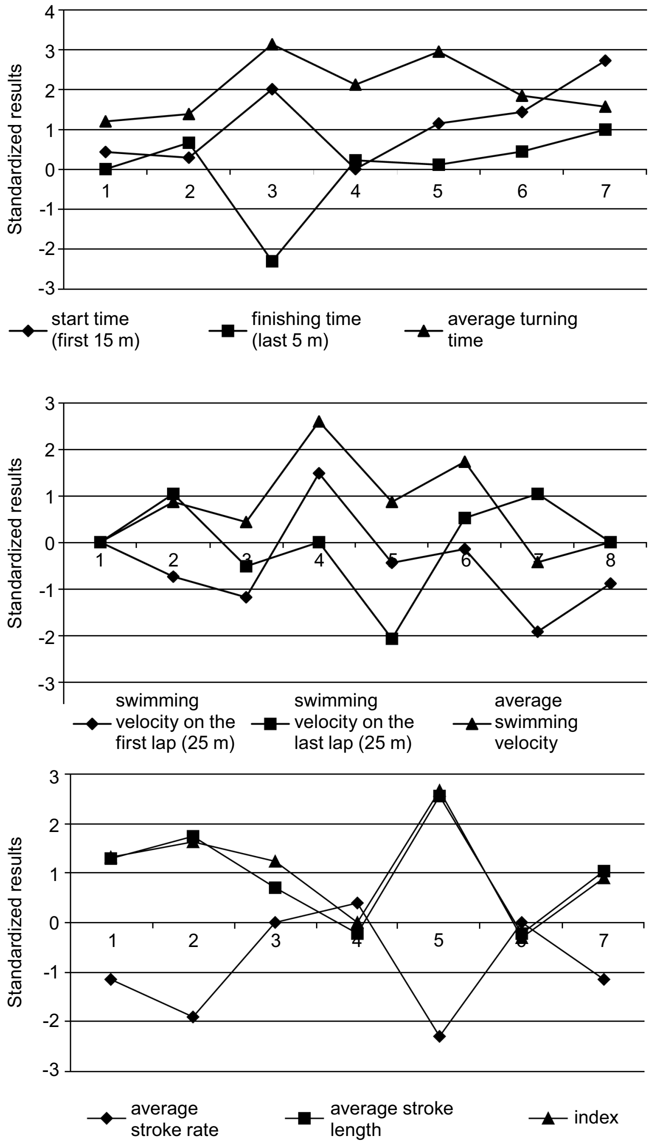

Figure 3. Kinematic parameters at 100 m women

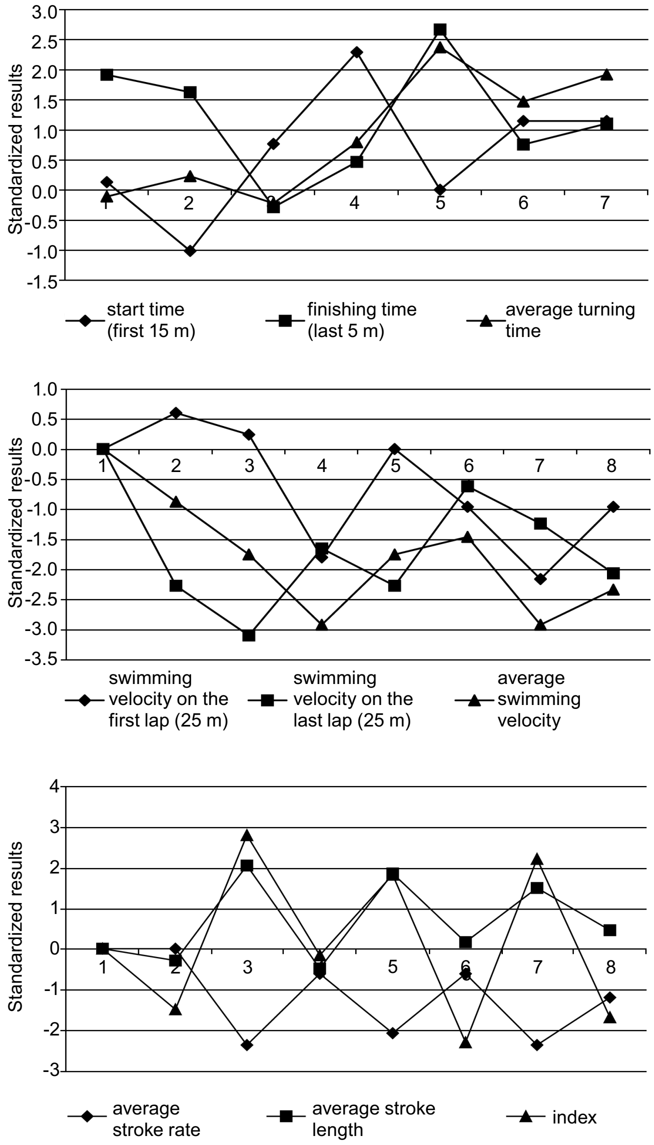

Figure 4. Kinematic parameters at 100 m men

stroke length (Fig. 4); 2nd–3rd in start time, average turning time and finishing time; and 4th as regards the W_s index.

Women butterfly 200 m

The winner of the 200 m race (B.B.) achieved the time of **2:06.62 min,** whereas the last finalist **2:09.05 min** (**2.43 s** difference) ($\bar{x}$ – 2:08.01 min, SD – 1.02, CV – 0.80 %). In terms of kinematic parameters, she was only the first in **finishing time** (2.84 s), 11.24% better than her competitors' (Fig. 5). She had the second average swimming velocity on the last lap and stroke rate, 6th–7th start time, 4th–5th stroke length, 6th turning time and the 4th W_s index.

Men butterfly 200 m

The difference between the best time (R.K.) (**1: 50.89 min)** and the worst time **(1:55.73 min**) was **4.84 s** ($\bar{x}$ – 1:53.83 min, SD – 1.50 s, CV – 1.32%). The winner also achieved the best results in **swimming velocity on the first lap** (1.92 m/s; 9.09% better than his competitors'), **average swimming velocity** (1.74 m/s, 9.09%), **finishing time** (2.55 s, 12.1%), and W_s index (3.67, 15.4%). In terms of kinematic parameters he had the second stroke length, 7th stroke rate, 2nd–3rd average turning time, 3rd swimming velocity on the final lap and 4th–5th start time.

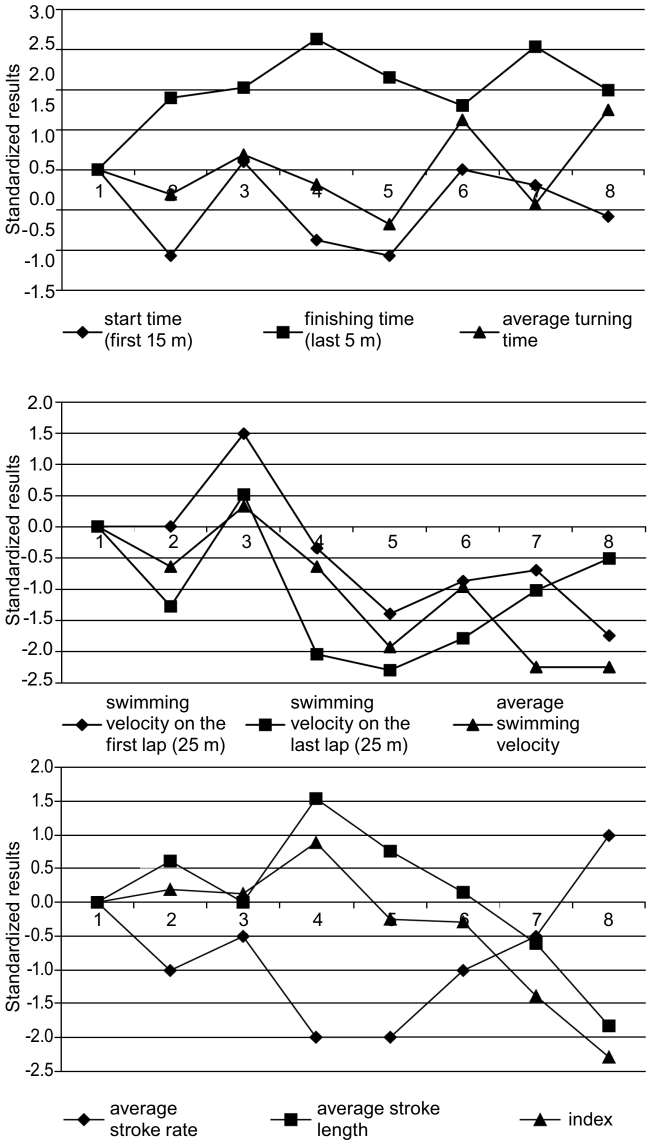

Figure 5. Kinematic parameters at 200 m women

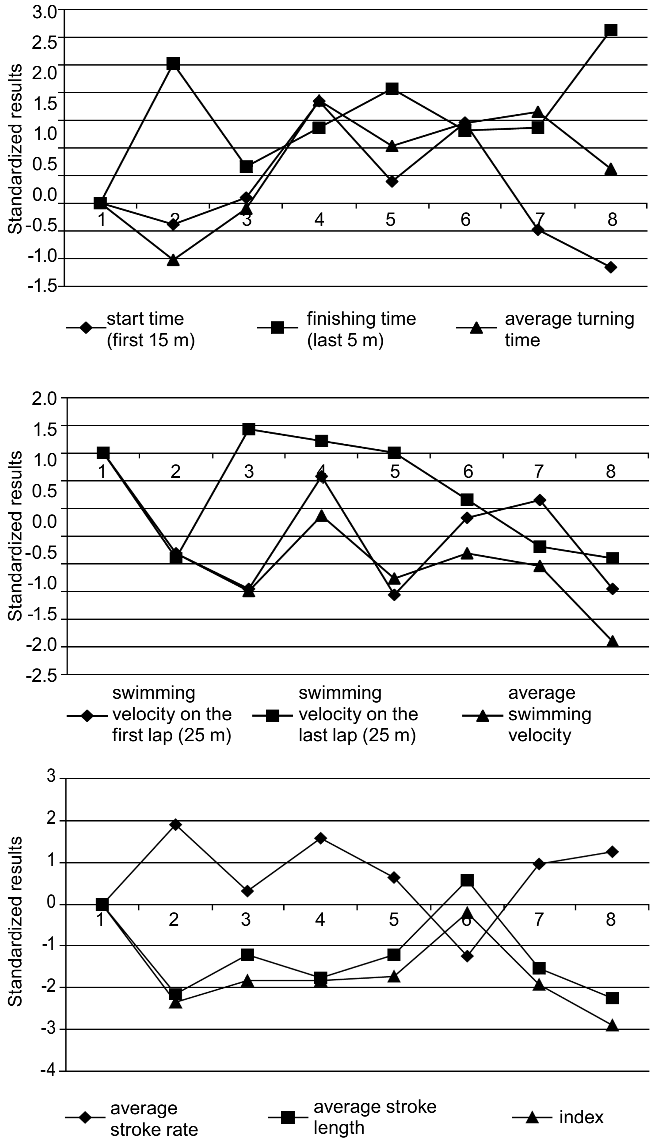

Figure 6. Kinematic parameters at 200 m men

Table 1. Pearson coefficients of correlation (*r*) between the swimmer's place in the finals and kinematic parameters

Kinematic parameters	Result					
	50 m		100 m		200 m	
	W	M	W	M	W	M
1. Start time (first 15 m)	**0.672**	**–0.669**	**0.718***	0.560	–0.011	–0.175
2. Swimming velocity on the first lap (25 m)	–0.610	–0.289	–0.319	–0.651	–0.696	–0.312
3. Swimming velocity on the last lap (25 m)	–0.307	–0.225	0.030	–0.072	–0.276	–0.476
4. Average turning time	0.417	0.396	**0.799***	**0.838****	0.314	**0.627**
5. Finishing time (last 5 m)	0.030	0.143	0.292	0.169	0.523	0.546
6. Average swimming velocity	**–0.695***	**–0.649**	–0.126	**–0.716***	**–0.845****	**–0.703***
7. Average stroke rate (F_c)	**–0.680***	–0.217	–0.089	–0.472	0.233	–0.046
8. Average stroke length (L_c)	0.080	0.153	0.037	0.260	–0.561	–0.194
9. Index of swimming velocity W_s	–0.205	0.059	0.003	**–0.716***	**–0.766***	–0.386

* $p > 0.05$, ** $p > 0.01$, W – women, M – men

Table 2. Statistical analysis of kinematic parameters at 50 m

Kinematic parameters	50 m					
	Women			Men		
	$\bar{x}$	SD	CV	$\bar{x}$	SD	CV
1. Start time (first 15 m)	6.81	0.15	**2.24**	5.82	0.15	**2.66**
2. Swimming velocity on the first lap (25 m)	1.75	0.06	**3.92**	1.95	0.05	**2.99**
3. Swimming velocity on the last lap (25 m)	1.70	0.02	**1.56**	1.91	0.03	**1.89**
4. Average turning time	8.23	0.09	**1.19**	7.30	0.08	**1.18**
5. Finishing time (last 5 m)	2.64	0.05	**2.18**	2.39	0.08	**3.67**
6. Average swimming velocity	1.72	0.04	**2.65**	1.93	0.02	**1.12**
7. Average stroke rate (F_c)	63.12	2.10	**3.32**	64.12	4.70	**7.33**
8. Average stroke length (L_c)	1.64	0.06	**3.99**	1.81	0.13	**7.60**
9. Index of swimming velocity W_s	2.83	0.17	**6.11**	3.48	0.26	**7.66**

Table 3. Statistical analysis of kinematic parameters at 100 m

Kinematic parameters	100 m					
	Women			Men		
	$\bar{x}$	SD	CV	$\bar{x}$	SD	CV
1. Start time (first 15 m)	7.14	0.13	**1.95**	5.98	0.15	**2.62**
2. Swimming velocity on the first lap (25 m)	1.65	0.06	**4.07**	1.86	0.08	**4.45**
3. Swimming velocity on the last lap (25 m)	1.51	0.02	**1.27**	1.72	0.03	**2.06**
4. Average turning time	8.80	0.10	**1.23**	7.82	0.08	**1.13**
5. Finishing time (last 5 m)	2.95	0.09	**3.08**	2.72	0.17	**6.33**
6. Average swimming velocity	1.59	0.02	**1.44**	1.81	0.03	**1.89**
7. Average stroke rate (F_c)	56.00	2.61	**4.67**	57.12	3.39	**5.95**
8. Average stroke length (L_c)	1.71	0.08	**5.02**	1.90	0.10	**5.61**
9. Index of swimming velocity W_s	2.73	0.15	**5.74**	3.43	0.18	**5.45**

Table 4. Statistical analysis of kinematic parameters at 200 m

Kinematic parameters	200 m					
	Women			Men		
	$\bar{x}$	SD	CV	$\bar{x}$	SD	CV
1. Start time (first 15 m)	7.44	0.10	**1.37**	6.44	0.20	**3.20**
2. Swimming velocity on the first lap (25 m)	1.62	0.11	**7.01**	1.78	0.09	**5.24**
3. Swimming velocity on the last lap (25 m)	1.42	0.03	**2.73**	1.57	0.04	**2.99**
4. Average turning time	9.60	0.08	**0.84**	8.41	0.09	**1.15**
5. Finishing time (last 5 m)	3.15	0.15	**4.97**	2.85	0.19	**6.95**
6. Average swimming velocity	1.50	0.03	**2.05**	1.65	0.04	**2.65**
7. Average stroke rate (F_c)	50.5	2.00	**3.96**	50.12	3.18	**6.34**
8. Average stroke length (L_c)	1.76	0.06	**3.70**	1.96	0.12	**6.35**
9. Index of swimming velocity W_s	2.65	0.13	**4.90**	3.22	0.27	**8.53**

Discussion

The analysis of kinematic parameters of men and women butterfly stroke swimmers taking part in the 50 m, 100 m and 200 m events at the European Championships in Trieste in 2005 was aimed to assess their impact on the competitors' results in the finals.

An analysis of standardized parameters (Fig. 1–6) shows that the winners of the 50 m, 100 m and 200 m events were not always in the lead in the kinematic parameters under study. The results showed that the women gold medalists differed most from their competitors in their 50 m **start time and turning time**; 100 m **turning time**; and 200 m **finishing time**. The men gold medalists reached the best swimming velocity results on the last lap at 50 m; best 100 m **average swimming velocity**, best **swimming velocity on the last lap** and, in particular, the best **stroke rate**. In the 200 m race the European Champion (R.K.) featured the highest **average swimming velocity**, **finishing time** and the **index of swimming efficiency (W_s).**

The results of the Pearson linear correlation (*r*) (Tab. 1) between the kinematic parameters and the swimmer's places in the finals point to the significance of **start time** in short-distance swimming (50 m and 100 m); **average turning time** at 100 m; and **average swimming velocity and** the **index of swimming efficiency** at 100 m men and 200 m women.

In order to examine the differences between individual kinematic parameters of the finalists, coefficients of variation for particular swimming events were calculated (Tab. 2–4). This allowed for differentiation of a few groups of subjects with regard to a particular parameter, or a set of a few parameters with regard to one group of subjects. All the coefficients of variance of the parameters under study fell between **0.84%** (average turning time – women 200 m) and **8.53%** (index of swimming efficiency – men 200 m). The swimmers' kinematic parameters with the greatest variation in all finals included **swimming velocity on the first lap** (especially women), **finishing time** (the higher the coefficients of variation, the longer the swimming distance) as well as **average stroke rate (F_c), average stroke length (L_c)** and, in particular, the **index of swimming efficiency (W_s).** The latter are swimmers' individual traits as their quantity depends on the swimmer's morphofunctional capacity. The swimmers with high average stroke length (L_c) featured low stroke rate (F_c), e.g. A.K. the winner of the women 50 m, and R.K. the winner of the men 200 m. The variability of these two parameters is inversely proportional [9, 15, 16], thus elite swimmers constantly improve their skills in order to maintain the longest stroke length possible and optimal stroke rate [6, 9, 11].

The average "pure swimming" velocity (in all events) featured slight variability, with coefficients of variation between 1.12 and 2.65%. Thus, the value of this parameter in all the swimmers under study was similar enough to be a decisive factor for victory. However, the coefficients of correlation (Tab. 1) between average swimming velocity and the place in the finals were statistically significant (with the exception of the women 100 m event). It can be assumed that swimming velocity was a decisive kinemtaic parameter in the case of all the swimmers, although it was slightly varied. This observation seems valid as the sample consisted of top European swimmers.

Conclusions

1. The examined kinematic parameters of butterfly stroke swimmers taking part in the European Championships were varied with regard to the swimming event and swimming distance.
2. The winners of individual women butterfly events had the best **start time, turning time, and finishing time**; whereas the winners of men events featured the best **average swimming velocity**, **average stroke rate (F_c)** and (in the case of the 200 m race) **index of swimming efficiency (W_s).**
3. Kinematic parameters most strongly correlated with the sports results were **start time** at 50 m in men and women and at 100 m in women, **average turning time** at 100 m, **index of swimming efficiency** (W_s) at 100 m men and 200 m women and the **average swimming velocity** at all distances apart from 100 m women.
4. A thorough analysis of the swimmers' technical and fitness indices seems justified and purposeful since monitoring and interpretation of changes of swimming technique parameters in crucial phases of the swimming distance allows proper scrutiny and programming, and it can be a useful guideline in training development leading to achievement of sport success.

References
1. Sozański H., Diversification of sport development of junior competitors depending on a type of training [in Polish]. AWF, Warszawa 1986.
2. Płatonow W.N., Sozański H. (ed.), Optimization of the sport training structure [in Polish]. RCMSKFiS, Warszawa 1991.
3. Ungerechts B., Volck G., Freitag W., Lehrplan Schwimmsport. Band 1. Technik [in German]. Hofmann, Schorndorf 2002.
4. Płatonow W.N., Professional training in swimming [in Polish]. RCMSKFiS, Warszawa 1997.
5. Hay J.G., The state of research on the biomechanics of swimming. In: Hay J.G. (ed.), Starting, Stroking and Turning. Biomechanics Laboratory, University of Iowa 1986, 53–76.
6. Aloes F., Cunha P., Gomes-Pereira J., Kinematic changes with inspiratory actions in butterfly swimming. In: Keskinen K.L., Komi P.V., Pitkänen P.L. (eds.), VIII International Symposium on Biomechanics and Medicine in Swimming. 32 Helsinki, Finland: University of Jyvaskyla, 1998.
7. Counsilman J.E., Competitive swimming manual for coaches and swimmers. Bloomington, Indiana 1987, 307.
8. Colwin C.M., Swimming into the 21st century. Leisure Press, Champaign 1992.
9. Bartkowiak E., Competitive swimming [in Polish]. COS, Warszawa 1999.
10. Adrian M., Singh M., Karpovich P., Energy cost of the leg kick, arm stroke and whole stroke. *J Appl Physiol*, 1996, 21, 1763–1766.
11. Cappaert J.M., Pease D.L., Troup J.P., Biomechanical highlights of world champion and Olympic swimmers. In: Troup J.P., Hollender A.P., Stresse D., Trappe S.W., Cappaert J.M., Trappe T.A. (eds.), Biomechanics and Medicine in Swimming VII. E & FN Spon, New York 1996, 76–80.
12. Maglischo E.W., Swimming even faster. Mayfield Publishing Company, Mountain View, California 1993.
13. Boomer W.L., Competitive Swimming, Lecture presented at the University of Texas – Austin, Austin 1996.
14. Sanders R.H., Cappaert J.M., Devlin R.K., Wave characteristics of butterfly swimming. *J Biomech*, 1995, 28(1), 9–16.
15. Hahn A., Krug T., Application of knowledge gained from the coordination of partial movements in breaststroke and butterfly swimming for the development of technical training. In: MacLaren D., Reilly T., Lees A. (eds.), Biomechanics and medicine in swimming. Swimming Science VI. E & FN Spon, New York 1992, 167–172.
16. Sanders R.H., Some aspects of butterfly technique of New Zealand Pan Pacific squad swimmers. In: Troup J.P, Hollander A.P., Strasse D., Trappe S.W., Cappaert J.M., Trappe T.A. (eds.), Biomechanics and Medicine in Swimming VII. E & FN Spon, New York 1996, 23–28.
17. Opyrchał C., Płatek Ł., Karpiński R., Analysis of Otylia Jędrzejczak's swimming in the 200 m butterfly stroke race at the World Swimming Championships in Barcelona (2003). In: Mynarski W., Ślężyński J., Effects of Education in Physical Culture [in Polish]. AWF, Katowice 2005, 291–299.
18. Smith D.J., Norris S.R., Hogg J.M., Performance evaluation of swimmers: Scientific Tools. *Sports Medicine*, 2002, 32(9), 539–554.
19. Haljand R., Technical and tactical parameters of competition. Available from: URL: http://www.swim.ee/competition analysis.
20. Ferguson G.A., Takane Y., Statistical analysis in psychology and pedagogy [in Polish]. PWN, Warszawa 1997.

Paper received by the Editors: July 6, 2006.
Paper accepted for publication: June 4, 2007.

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HUMAN MOVEMENT
2007, vol. 8 (2), 112–119

SWIMMING TECHNIQUE AND BIOMETRIC AND FUNCTIONAL INDICES OF YOUNG SWIMMERS IN RELATION TO FRONT CRAWL SWIMMING VELOCITY

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ABSTRACT
Front crawl swimming velocity is related to the swimming technique, i.e. it is modified by the swimmer depending on the swimming distance. The technique mastery also determines the athlete's somatic indices and physiological abilities. **Purpose.** The purpose of the study was to examine factors affecting front crawl swimming results at distances of 400 m, 100 m and 25 m in elite young swimmers. **Basic procedures.** The athletes were divided into two age groups (n = 15): G1 (16.8 ± 0.77 years) and G2 (14.7 ± 0.50 years). Five laboratory tests were carried out: one for anaerobic power – vertical jump test (CMJ), two one-minute-long anaerobic endurance tests with arms (TWAR) and legs (TWLG), and two incremental tests to assess the anaerobic threshold for arms ($WL_{LT}AR$) and legs ($WL_{LT}LG$). Swimming tests were performed at distances of 400, 100 and 25 m to measure the stroke rate (SR), stroke length (SL) and arm coordination index (IdC). **Main findings.** Swimming velocity in the 400 m race revealed the strongest correlation with SR, further indices obtained from the regression analysis were SL400 and $WL_{LT}AR$. At a distance of 100 m swimming velocity was determined by power indices such as the CMJ test, SR100 and IdC. The velocity at 25 m was dependent on the greatest number of indices, i.e. SR25, CMJ, SL and IdC. **Conclusion.** Front crawl swimming velocity at different distances depends equally on stroke length (SL) or arm movement trajectory as well as stroke rhythm (SR and IdC) individually, matching the swimmer's functional capability.

Key words: swimming, stroking parameters, oxygen consumption, anaerobic threshold

Introduction

Front crawl swimming velocity depends to a great extent on the swimming technique, the components of which are modified depending on the swimming distance. The swimming time ranges from 20 s in short-distance events to several minutes at long distances. The use of a swimming technique over a given distance depends, first of all, on the swimmer's somatic properties, e.g. lean body mass (LBM) and body total length (BTL), and physiological indices (aerobic and anaerobic capacity) [1–6]. An analysis of the body's physiological reactions to physical effort (e.g. lactate blood concentration (La) and indices of gas exchange) as well as relationships between physiological and motor variables and front crawl swimming velocity can yield a great deal of information for proper management of swimming training. In the past, the model of crawl swimming was a result of the coach's subjective imagining of movement patterns suitable for each technique. In the late 1970s the swimming technique assessment was objectivized by measurement of such parameters as arms stroke length (SL) and stroke rate (SR). Depending on the swimmers' training level and swimming distance these parameters can vary significantly. In young swimmers, the correlation between the training level and front crawl swimming velocity can change. In the opinion of many coaches and researchers front crawl swimming results are most strongly correlated with the arms stroke length (SL), which is a reflection of the applied training methods [7, 8].

Video recording of swimming movements, used for the first time during the Seoul Olympics in 1988, allowed detailed analysis of swimming techniques. In recent years, underwater video recording has been used for the purpose of accurate analysis of movement structure. Thanks to video recording it is currently possible to assess such swimming parameters as arm stroke rate, stroke length and index of coordination (IdC) [9–11]. The available assessment tools have made it possible to

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examine the hierarchy of significance of factors affecting front crawl swimming results at distances of 400, 100 and 25 m among competitive swimmers.

Material and methods

The study was carried out among 30 swimmers at a high training level from a sports school. The sample did not include breaststroke swimmers. The swimmers were divided into two age groups of 15 subjects each: G1 (16.8 ± 0.77 years) and G2 (14.7 ± 0.50 years) (Tab. 1). The swimmers under study were in the IV and V Tanner stages. In G1 nine subjects featured the mesomorphic body type, and six the ectomorphic type. In G2 there were 10 and 5 subjects of each somatotype, respectively (after Carter-Heath [3]). The body total length (BTL) was measured from the finger tips to the toe tips. Lean body mass was assessed with the use of the method of Slaughter et al. [12].

The statistical analysis, including coefficients of correlation, statistical significance for independent variables and hierarchical analysis of regression was carried out with the aid of SPSS (Version 12, USA). The hierarchical analysis of regression with athletes' calendar age used coefficients of correlations not higher than $r = 0.6$. This allowed incorporation of the swimmers' calendar age into the research model for each test, followed by other variables.

Laboratory and swimming tests

Each subject underwent five laboratory tests:
– anaerobic power test (vertical jump test – CMJ),
– incremental tests for assessment of arms ($\dot{V}O_{2max}$AR) and legs aerobic capacity ($\dot{V}O_{2max}$LG),
– One-minute anaerobic endurance tests for arms (TWAR) and legs (TWLG).

The arms tests ($\dot{V}O_{2max}$AR and TWAR) were performed by subjects in a sitting position, with the use of the 834E-Ergomedic ergometer, Monark (Sweden). The $\dot{V}O_{2max}$LG legs aerobic capacity test was performed on the ER 900 Jaeger cyclometer (Germany), and the TWLG test on the 874E-Ergomedic cyclo ergometer, Monark (Sweden). The maximal force and quantity of work during one vertical jump (CMJ) was recorded using the Opto Jump recorder (Italy).

The ergometer braking force was set for each subject at 7.5% BM in TWLG and at 4.5% in TWAR [13, 14]. The incremental $\dot{V}O_{2max}$LG test was preceded by a three-minute warm-up (WU) at intensity of about 45% $\dot{V}O_{2max}$, after which it was increased by about 30 W, every three minutes. The intensity of exercise during the warm-up was 150 W in G1 and 120 W in G2. The $\dot{V}O_{2max}$AR test was preceded with a warm-up of 90 W in G1 and 60 W in G2, and then the intensity was gradually increased every three minutes, for 18 W and 12 W, respectively. The incremental exercises were performed at 70 rpm^{-1} in $\dot{V}O_{2max}$LG and at 60 rpm^{-1} in $\dot{V}O_{2max}$AR. The gas exchange indices were calculated using the 919ER MEDIKRO meter (Finland). During the last 30 s of the workload in the $\dot{V}O_{2max}$AR and $\dot{V}O_{2max}$LG tests blood samples were drawn from the subjects' ear lobes to mark the lactate concentration (La), using the PLUS DR LANGE Miniphotometer (Germany). The procedure adopted in both incremental tests made it possible to determine the anaerobic threshold AT (WL_{LT}AR and WL_{LT}LG) with the use of the Dmax method [15, 16] as well as the maximal oxygen uptake ($\dot{V}O_{2max}$AR and $\dot{V}O_{2max}$LG) ($l \cdot min^{-1}$).

The elevation of the center of gravity during the vertical jump (CMJ) was assessed using the jump duration. Work during the jump (*W*) was calculated according to formula (2).

$$\Delta h = \frac{gt_l^2}{8} \quad (1)$$

$$Wmg\Delta h = \frac{mg^2t_l^2}{8} \quad (2)$$

W – work during the jump (J)
g – gravitational acceleration ($m\ s^{-2}$)
Δh – elevation of the center of gravity (m)
m – body weight (kg)
t_l – jump duration (s)

The 400 m, 100 m and 25 m swimming tests were carried out in a 50 m-long swimming pool. The swimmers' movements were recorded using a GRV 9800 JVC underwater camera (Japan) from the side of the pool, 1 m below the water surface, about 6 m from the moving swimmer, at 50 frames per second. The obtained footage allowed identification of the following swimming technique parameters: arms stroke rate (SR), index of coordination (IdC) and arm movement phases – entry (E), pull (PL), push (PS) and recovery (R) (after Chollet et al. [9]). These parameters were marked at swimming distances of 100 m and 25 m, out of three full arm movement cycles, and at a distance of 400 m out of two cycles. The arms stroke length (SL) at individual distances was calculated from the stroke rate results and mean swimming velocity at a distance of 20 m, with the exception of a 5 m-zone before each return. The duration of the entire swimming race and individual sections was measured with a stopwatch to 0.01 s. The front crawl parameters were assessed on the basis of the video recording after the 2nd, 4th, 8th and 10th pool lengths at 400 m, and after each pool length during the 100 m test. The arterialized blood sample was drawn from the ear lobe three minutes after compling the swimming tests. The blood lactate (La) concentration was marked with the aid of the PLUS DR LANGE Miniphotometer (Germany).

In front crawl swimming the arm movements are cyclic, thus the analysis of the footage made it possible to divide the stroke into phases, following the method of Chollet et al. [9] (Fig. 1).

The arm stroke cycle phases were first identified as propulsive and non-propulsive: the entry phase (E) (non-propulsive) from the arm's entry into the water to the onset of its movement backwards; the pull phase (PL) (propulsive) from the start of the arm movement backwards till it stops in front of the chest with the hand pointing downwards; the push phase (PS) from the end of the pull phase until its recovery from the water; and the recovery phase (R) from the arm's recovery to its re-entry.

Fig. 2 presents arm movement coordination ("catch up") with non-propulsive time lag (P) periods (IdC < 0) between the propulsive phases.

In the assessment of arm movement coordination the index of coordination (IdC) has been used. It is expressed as percentage of the cycle length, similarly to all phases of the stroke cycle:

$$IdC = \frac{t_R^{k1} - t_{PL}^{k2}}{T_c} \cdot 100\% \qquad (3)$$

where

IdC – index of coordination,
t_R^{k1} – start of the recovery phase (R) for the first arm,
t_{PL}^{k2} – start of the pull phase (PL) for the second arm,
T_C – total duration of the stroke cycle.

In the case of overlapping phases IdC was positive, and in the event of time lag between the phases it was negative.

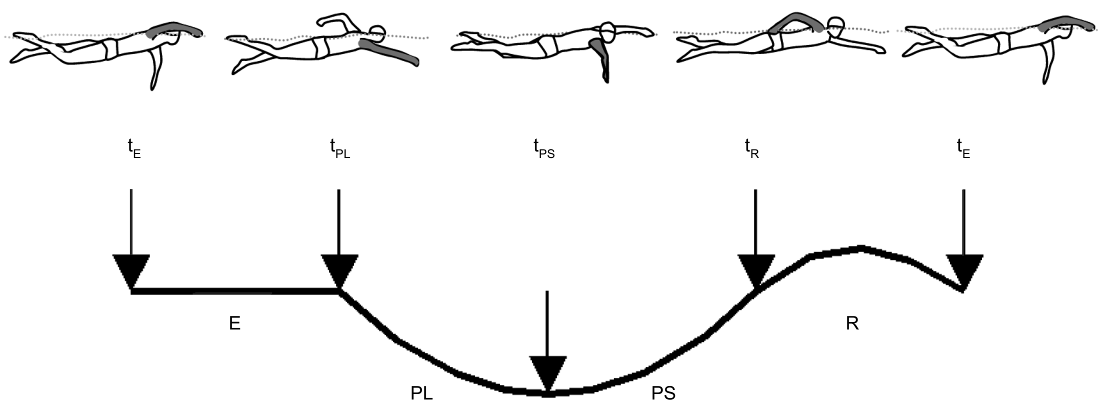

Figure 1. Arm stroke cycle phases in front crawl swimming

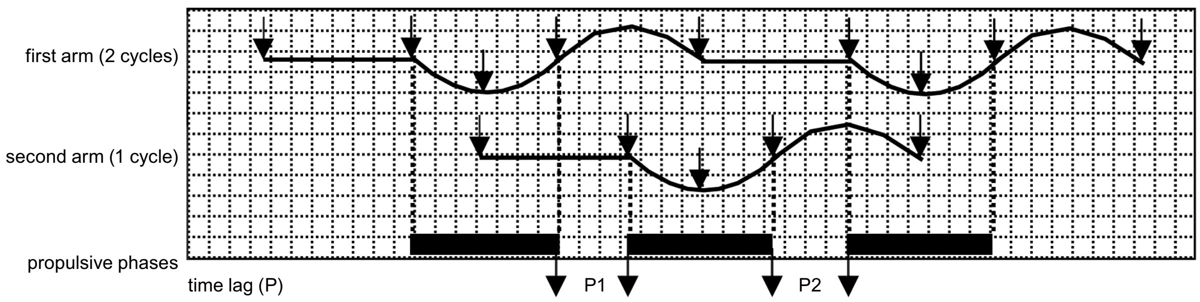

Figure 2. Arm movement coordination ("catch up")

Results

The swimmers' anaerobic capacity, assessed on the basis of the results of one-minute tests, revealed significant differences in G1 and G2. In the group of older swimmers (G1), it was significantly higher in the CMJ, TWAR and TWLG tests than in the group of the younger swimmers (G2) (Tab. 1). In both incremental tests, the anaerobic threshold values also differed significantly between the two groups (Tab. 1). The maximal one-minute oxygen uptake in the $\dot{V}O_{2max}$AR test was significantly higher in G1; however, it was not different per kg of body mass. In the $\dot{V}O_{2max}$LG test the absolute $\dot{V}O_{2max}$ results were not significantly different, however, in relative values they were 9% higher in G2 than in G1.

Table 1. Biometric and somatic parameters and physical capacity of swimmers from G1 and G2

Parameter	G1 (*n* = 15) $\bar{x} \pm$ SD	G2 (*n* = 15) $\bar{x} \pm$ SD
Age (years)	16.80 ± 0.77	14.70 ± 0.49*
BH (cm)	182.20 ± 6.05	175.70 ± 6.55*
BTL (cm)	252.70 ± 9.43	243.40 ± 10.51*
AS (cm)	187.00 ± 7.79	180.30 ± 8.13*
BM (kg)	70.80 ± 5.40	62.40 ± 6.00**
LBM (kg)	62.50 ± 4.47	56.20 ± 5.25*
CMJ (J)	299.52 ± 35.36	259.15 ± 41.11*
TWAR (kJ)	318.47 ± 40.57	272.93 ± 44.65*
TWLG (kJ)	521.20 ± 42.47	455.33 ± 57.97*
WL_{LT} AR (W)	124.80 ± 18.59	104.27 ± 14.42*
WL_{LT} LG (W)	210.00 ± 27.77	178.00 ± 28.83*
$\dot{V}O_{2max}$AR ($l \cdot min^{-1}$)	3.13 ± 0.38	2.83 ± 0.33*
$\dot{V}O_{2max}$LG ($l \cdot min^{-1}$)	3.71 ± 0.37	3.56 ± 0.29
$\dot{V}O_{2max}$AR ($ml \cdot min^{-1}$)	44.51 ± 6.10	45.61 ± 4.94
$\dot{V}O_{2max}$LG ($ml \cdot min^{-1}$)	52.75 ± 6.45	57.96 ± 6.33*

BH – body hight, BTL – body total length, AS – arms stretch, BM – body mass, LBM – lean body mass, CMJ – anaerobic power – vertical jump test, TWAR – anaerobic endurance test for arms, TWLG – anaerobic endurance test for legs, WL_{LT}AR – anaerobic threshold AT for arms, WL_{LT}LG – anaerobic threshold AT for legs, $\dot{V}O_{2max}$AR ($l \cdot min^{-1}$) – maximal oxygen uptake for arms, $\dot{V}O_{2max}$LG ($l \cdot min^{-1}$) – maximal oxygen uptake for legs, $\dot{V}O_{2max}$AR ($ml \cdot min^{-1}$) – incremental test for assesment of arms aerobic capacity, $\dot{V}O_{2max}$LG ($ml \cdot min^{-1}$) – incremental test for assesment of legs aerobic capacity, * $p < 0.05$, ** $p < 0.001$

At all swimming distances the mean swimming velocity (V) and stroke length (SL) were statistically significantly higher in the group of older swimmers (G1) than in the group of younger swimmers (G2). At individual distances, from 25 to 400 m, the stroke rate values (SR) decreased along with the decrease in swimming velocity (Tab. 2). In contrast, SL generally increased as the swimming velocity (V) decreased (Tab. 2). The IdC and propulsive arm stroke phases (PL+PS) as well as SR were mostly higher at shorter swimming distances. In G2 at 400 m swimming velocity was significantly correlated with SR, IdC, propulsive (PL+PS) and non-propulsive (E+R) phases as well as BM, BTL, AS and WL_{LT}AR (Tab. 3). In G1, such high correlations were not observed and swimming velocity was correlated at the level of statistical significance only with SR and AS. At the shortest swimming distances the linear correlations between swimming velocity (V) and other parameters were varied (Tab. 3).

The level of post-exercise blood lactate concentration in laboratory tests and after swimming tests was one of the body workload indices in individual tests. After the swimming races at 100 m and 400 m a statistically significant lactate concentration was noted in both groups of swimmers (Tab. 4).

The analysis of regression (Tab. 5) revealed the impact of the calendar age on the test results. For instance, swimming velocity (V) at 400, 100 and 25 m depended on the swimmers' age in 46.4%, 46.2% and 29%, respectively.

Having considered all other variables the percentage of variance amounted significantly to 81.9%, 77.0% and 86.8%, respectively. The analysis of regression with the calendar age yielded statistically significant predictors of swimming velocity at the examined distances for the entire sample. The velocity (V) at 400 m is highly correlated with the arms stroke rate (SR400) (Tab. 6A). A statistically significant correlation at the same distance was noted between V and the arms stroke length (SL400), whereas the WL_{LT}AR index was barely statistically significant. The swimming velocity at 100 m was significantly correlated with work in the CMJ test and was on the verge of statistical significance with the arms stroke rate SR100 and index of coordination (IdC) (Tab. 6B). The swimming velocity at 25 m was correlated with the highest number of variables: IdC25, SR25, SL25 and CMJ (Tab. 6C).

Table 2. Swimming technique parameters at 400, 100 and 25 m

Distance (m)	Group	V ($m \cdot s^{-1}$)	SR ($cycles \cdot min^{-1}$)	SL (m)	IdC (%)	E (%)	PL (%)	PS (%)	R (%)	PL+PS (%)	E+R (%)
	G1	1.47 ± 0.05	37.28 ± 4.00	2.29 ± 0.21	–9.3 ± 6.38	35.4 ± 7.65	15.1 ± 3.96	26.30 ± 3.71	23.2 ± 2.86	41.4 ± 6.14	58.6 ± 6.14
400	G2	1.40 ± 0.05*	40.38 ± 4.74	2.08 ± 0.21*	–3.0 ± 7.54*	31.4 ± 9.47	16.7 ± 2.83	28.04 ± 5.09	23.8 ± 3.37	44.8 ± 7.09	55.3 ± 7.09
	G1+G2	1.43 ± 0.06	38.83 ± 4.59	2.18 ± 0.23	–6.2 ± 7.58	33.4 ± 8.70	15.9 ± 2.97	27.17 ± 4.47	23.5 ± 3.09	43.1 ± 6.74	56.9 ± 6.74
	G1	1.71 ± 0.04	47.98 ± 3.68	2.08 ± 0.17	0.3 ± 5.71	23.1 ± 5.11	19.4 ± 6.47	30.52 ± 4.44	27.0 ± 5.24	49.9 ± 6.11	50.1 ± 6.11
100	G2	1.63 ± 0.06**	48.57 ± 4.47	1.90 ± 0.15*	4.2 ± 5.02	23.0 ± 7.39	20.4 ± 3.20	30.81 ± 4.16	25.8 ± 3.67	51.2 ± 6.16	48.8 ± 6.16
	G1+G2	1.67 ± 0.06	48.27 ± 4.03	1.99 ± 0.19	2.3 ± 5.65	23.0 ± 6.24	19.9 ± 5.04	30.66 ± 4.23	26.4 ± 4.49	50.6 ± 6.06	49.4 ± 6.06
	G1	1.78 ± 0.07	54.07 ± 4.31	1.95 ± 0.12	1.4 ± 7.22	21.8 ± 5.58	19.3 ± 3.03	31.19 ± 2.78	27.7 ± 2.86	50.5 ± 4.97	49.5 ± 4.97
25	G2	1.72 ± 0.07*	57.04 ± 4.98	1.80 ± 0.16*	2.7 ± 5.71	19.3 ± 6.90	20.9 ± 3.98	30.04 ± 2.81	29.8 ± 3.34	50.9 ± 5.50	49.1 ± 5.50
	G1+G2	1.75 ± 0.07	55.56 ± 4.82	1.87 ± 0.16	2.1 ± 6.43	20.6 ± 6.29	20.1 ± 3.56	30.62 ± 2.81	28.7 ± 3.23	50.7 ± 5.15	49.3 ± 5.15

V – swimming velocity, SR – stroke rate, SL – stroke length, IdC – index of coordination, E – entry phase, PL – pull phase, PS – push phase, R – recovery phase, PL+PS – propulsive phases, E+R – non-propulsive phases, $^{*}p < 0.05$, $^{**}p < 0.001$

Table 3. Selected correlations between swimming velocity at 400, 100 and 25 m and swimming technique, somatic and functional parameters

V ($m \cdot s^{-1}$)	Group	SL (m)	SR ($cycles \cdot min^{-1}$)	IdC (%)	PL+PS (%)	E+R (%)	BM (kg)	LBM (kg)	BTL (cm)	AS (cm)	CMJ (J)	TWAR (kJ)	TWLG (kJ)	$\dot{V}O_{2max}$ ($l \cdot min^{-1}$)		WL_{LT} (W)	
														AR	LG	AR	LG
400	G1	0.01	0.46	0.35	0.16	–0.16	0.25	0.14	0.38	0.47	–0.07	0.33	0.40	0.06	–0.41	0.21	–0.07
	G2	–0.42	0.54*	0.31	0.56*	–0.56*	0.27	0.44	0.58*	0.50	0.37	0.30	0.22	0.29	0.45	0.54*	0.35
100	G1	0.19	0.20	0.34	0.62*	–0.62*	0.08	0.31	0.38	0.34	0.32	0.40	0.24	–0.08	0.02	0.07	0.36
	G2	0.03	0.52*	0.66*	0.04	–0.04	0.55*	0.59*	0.35	0.30	0.70*	0.58*	0.64*	0.44	0.55*	0.57*	0.51*
25	G1	–0.07	0.65*	0.70*	0.12	–0.12	0.04	0.26	0.24	0.18	0.54*	0.47	0.18	–0.02	0.20	0.11	0.37
	G2	–0.06	0.42	0.36	0.29	–0.29	0.78**	0.72*	0.41	0.39	0.79**	0.75*	0.86**	0.40	0.41	0.53*	0.59*

SL – stroke length, SR – stroke rate, IdC – index of coordination, PL+PS – propulsive phases, E+R – non-propulsive phases, BM – body mass, LBM – lean body mass, BTL – body total length, AS – arms stretch, CMJ – anaerobic power – vertical jump test, TWAR – anaerobic endurance test for arms, TWLG – anaerobic endurance test for legs, $\dot{V}O_{2max}$ ($l \cdot min^{-1}$) – maximal oxygen uptake, WL_{LT} – anaerobic threshold AT, $^{*}p < 0.05$, $^{**}p < 0.001$

Table 4. Post-exercise lactate blood concentration (La) measured three minutes after the anaerobic tests and swimming tests in G1 and G2

Group	La (TWAR) ($mmol \cdot l^{-1}$)	La (TWLG) ($mmol \cdot l^{-1}$)	La (25 m) ($mmol \cdot l^{-1}$)	La (100 m) ($mmol \cdot l^{-1}$)	La (400 m) ($mmol \cdot l^{-1}$)
G1	11.49 ± 2.03	16.45 ± 1.51	7.42 ± 1.18	12.62 ± 3.37	11.55 ± 2.48
G2	12.68 ± 2.32	15.86 ± 2.18	6.73 ± 1.71	10.33 ± 1.36*	8.99 ± 2.16*

Table 5. Analysis of variance of calendar age and selected morphological, physiological and swimming technique variables

n = 30		R	R^2	change R^2	F for change	*p* <
V400	age	0.681	0.464	0.464	24.243	0.001
	variables	0.905	0.819	0.355	7.194	0.001
V100	age	0.680	0.462	0.462	24.051	0.001
	variables	0.877	0.770	0.308	4.908	0.003
V25	age	0.538	0.290	0.290	11.421	0.002
	variables	0.932	0.868	0.579	20.239	0.001

Discussion

The swimming velocity at 400 m in G2 was highly correlated with two front crawl swimming parameters: SR400 and IdC400 and propulsive stroke phases (PL+PS). In G1 these correlations were not that strong. The analysis of regression results for the entire sample of 30 swimmers (Tab. 6A) showed that SR400 had the greatest impact on swimming velocity (V) at 400 m. Also SL400 and $WL_{LT}AR$ were statistically significantly correlated with swimming velocity. A high significant correlation was also observed between swimming velocity at 400 m and IdC ($\beta = 0.379$, $t = 2.125$, $p = 0.045$). IdC, which was highly correlated with SR ($r = 0.78$, $p < 0.01$), was part of the regression equation. In G2 the swimmers' body total length (BTL) was significantly correlated with swimming velocity at 400 m; however, the analysis of regression with the swimmers' calendar age revealed no correlation at all. Our results are in accordance with results obtained by Pelayo et al. [17] and Chatard et al. [18], who did not observe any correlation between swimming velocity (V) and swimmers' BTL at 400 m. In contrast, Grimston et al. [2] noted that somatic characteristics were significant determinants of swimming velocity (V) and front crawl swimming technique at distances from 50 to 1000 yards.

We are of the opinion that the observed significant correlation between the index of coordination (IdC) and swimming velocity (V) at a distance of 400 m is a proof of the swimmers' efficacy and a high level of swimming technique mastery. The increasing IdC corresponded to a decrease in non-propulsive arms stroke phases (E+R). It should be emphasized that the index of coordination (IdC) and stroke rate (SR) were highly, negatively correlated with stroke length (SL). The latter is also a decisive determinant of the swimmer's technical skills, which has been noted by many researchers before [4, 17, 19–22]. It is, at the same time, a factor underestimated by some coaches and athletes. It seems, therefore, that the IdC, SR and SL values can be used in assessment of the front crawl swimming technique, as they most strongly determine the swimming velocity at longer distances.

The swimming velocity at short distances depends primarily on the efficacy of anaerobic metabolism, which is expressed by a high correlation between the swimming velocity (V), CMJ test, TWAR and TWLG test results. The significant role of the anaerobic changes is evidenced by the post-exercise lactate blood concentration (La), which was the highest after the 100 m race. The TWAR and TWLG could not be incorporated into a single training model because of their high mutual correlation with CMJ. An analysis of the performed tests in terms of the swimmers' energy expenditure may suggest that the result at short swimming distances is primarily determined by the swimmer's capacity. Short-distance swimmers feature greater lean body mass (LBM) and body total length (BTL) [2, 6, 18, 21].

Increasing swimming velocity requires significantly greater energy expenditure than increasing running velocity. Water has obviously a far greater density and drag than air [23, 24]. According to Kolmogorov et al. [5] in-

Table 6. Coefficients of correlation of physiological, morphological and swimming technique parameters with swimming velocity at distances of 400 m (A), 100 m (B) and 25 m (C)

A	V400		
	β	*t*	*p* <
Constant	–	0.424	0.676
SR 400 (cycles·min^{-1})	**1.036**	**4.595**	**0.001**
SL 400 (m)	**0.544**	**2.242**	**0.035**
TWAR (kJ)	0.114	0.731	0.473
$\dot{V}O_{2max}$AR (l·min^{-1})	0.185	1.500	0.148
WL_{LT} AR (W)	***0.284***	***1.930***	***0.067***
BTL (cm)	–0.035	–0.255	0.801
B	**V100**		
	β	*t*	*p* <
Constant	–	4.460	0.001
IdC (%)	***0.281***	***1.909***	***0.069***
SR100 (cycles·min^{-1})	***0.258***	***1.831***	***0.081***
SL100 (m)	0.159	1.055	0.303
CMJ (J)	**0.484**	**3.576**	**0.002**
$\dot{V}O_{2max}$AR (l·min^{-1})	0.060	0.438	0.666
BTL (cm)	–0.111	–0.719	0.480
C	**V25**		
	β	*t*	*p* <
Constant	–	1.339	0.194
IdC (%)	**0.271**	**3.054**	**0.006**
SR25 (cycles·min^{-1})	**0.721**	**5.057**	**0.001**
SL25 (m)	**0.530**	**3.258**	**0.003**
CMJ (J)	**0.518**	**5.127**	**0.001**
BTL (cm)	–0.036	–0.363	0.720

SR – stroke rate, SL – stroke length, TWAR – anaerobic endurance test for arms, $\dot{V}O_{2max}$AR (l·min^{-1}) – maximal oxygen uptake for arms, WL_{LT}AR – anaerobic threshold for arms, BTL – body total length, IdC – index of coordination, CMJ – anaerobic power – vertical jump test, $p < 0.05$

dividual adjustment of the movement biomechanical structure is crucial for reduction of hydrodynamic drag in front crawl swimming. At long and middle swimming distances a lower arms stroke rate (SR) and longer SL were noted than at short swimming distances. The arm work at long distances was highly correlated with the quantity of non-propulsive phases and with a decrease in IdC. Long-distance swimming with a longer entry phase (E) is economical and reduces hydrodynamic drag [9, 11]; however, it does not allow attaining higher velocity. Fast swimming requires an increase in the number of propulsive movements (PL+PS) and a simultaneous reduction in the quantity of non-propulsive ones (E+R). In the present study an increase in swimming velocity (V) at short distances was correlated with the increase in SR and IdC. This type of movement performance is related to the swimmer's ability to alter the synchronization pattern from "catch up" to "superposition", i.e. to overlapping propulsive phases [19]. An increased arms stroke rate and synchronization change allows the swimmer to overcome the mounting water head resistance.

The knowledge of the constituents of the front crawl swimming technique can be used by swimming coaches in more accurate modeling of the swimming technique. Underwater recording of the swimmer's propulsive movements has provided researchers [9, 11] with a great deal of scientific data which could be effectively put in practice. In the front crawl swimming at various distances not only the arms stroke length (SL) and trajectory are important, but also the stroke rate (SR) and index of coordination (IdC), which are adjusted to current functional capabilities of the swimmer's body.

Video recording of the swimmer's movements from both sides of the pool would definitely allow a more accurate and complex analysis of coordination of the entire arms stroke cycle [25]. It can be an important contribution to the process of optimization of the front crawl swimming technique.

References

1. Holmer I., Physiology of swimming man. *Acta Physiol Scand*, 1974, 407, (Suppl.), 1–55.
2. Grimston S.K., Hay J.G., Relationships among anthropometric and stroking characteristics of college swimmers. *Med Sci Sports Exerc*, 1986, 18, 60–68.
3. Carter J.E., Heath B.H., Somatotyping development and applications. Cambridge Studies in Biological Anthropology. Cambridge University Press, New York 1990.
4. Wakayoshi K., Yoshida T., Ikuta Y., Mutoh Y., Miyashita M., Adaptations to six-month aerobic swim training. Changes in velocity, stroke rate, stroke length and blood lactate. *Int J. Sports Med*, 1993, 14, 368–372.
5. Kolmogorov S.V., Rumyantseva O.A., Gordon B.J., Cappaert J.M., Hydrodynamic characteristics of competitive swimmers of different genders and performers levels. *J Appl Biomech*, 1997, 13, 88–97.
6. Strzała M., Tyka A., Żychowska M., Woźnicki P., Components of physical work capacity, somatic variables and technique in relation to 100 and 400m time trials in young swimmers. *J Hum Kinetics*, 2005, 14, 105–116.
7. Kennedy P., Brown P., Chengular S.N., Nelson R.C., Analysis of male and female Olympic swimmers in the 100-meter events. *Int J Sports Biomech*, 1990, 6, 187–197.
8. Arellano R., Brown P., Cappaert J., Nelson R.C., Analysis of 50-, 100-, and 200-m freestyle swimmers at the 1992 Olympic Games. *J Appl Biomech*, 1994, 10, 189–199.

9. Chollet D., Chalies S., Chatard J.C., A New index of coordination for the crawl: description and usefulness. *Int J Sports Med*, 2000, 21, 54–59.
10. Millet G.P., Chollet D., Chalies S., Chatard J.C., Coordination in front crawl in elite triathlets and elite swimmers. *Int J Sports Med*, 2002, 23, 99–104.
11. Seifert L., Chollet D., Bardy B.G., Effects of swimming velocity on arm coordination in the front crawl. *J Sports Sci*, 2004, 22, 651–660.
12. Slaughter M.H., Lohman T.G., Boileau R.A., Horswill C.A., Stillman R.J., Van Loan D. et al., Skinfold equations of body fatness in children and youth. *Hum Biol*, Wayne State University Press,1988, 60, 709–723.
13. Bar-Or O., Wingate anaerobic test. An update on methodology, reliability and validity. *Sports Medicine*, 1987, 4, 381–394.
14. Lutosławska G., Hübner-Woźniak E., Sitkowski D., Plasma glucose and blood lactate response to incremental cycling until exhaustion in active young men with different maximal oxygen uptake. *Biology of Sport*, 1995, 12, 137–143.
15. Cheng B., Kuipers H., Snyder A.C., Keizer H.A., Jeukendrup M., Hesselink M., New approach for the determination of ventillatory and lactate thresholds. *Int J Sports Med*, 1992, 13, 518–522.
16. Strzała M., Tyka A., Żychowska M., Reliability of invasive and non-invasive anaerobic threshold estimation in young swimmers. *J Hum Kinetics*, 2004, 12, 135–146.
17. Pelayo P., Sidney M., Kherif T., Chollet D., Tourny C., Stroking characteristics in freestyle swimming and relationships with anthropometric characteristics. *J Appl Biomech* 1996, 12, 197–206.
18. Chatard J.C., Lavoie J.M., Lacour J.R., Analysis of determinants of swimming economy in front crawl. *Eur J Appl Physiol*, 1990, 61, 88–92.
19. Chatard J.C., Collomp C., Maglischo E., Maglischo C., Swimming skill and stroking characteristics of front crawl swimmers. *Int J Sports Med*, 1990, 11, 156–161.
20. Touissaint H.M., Beek P.J., Biomechanics of competitive front crawl swimming. *Sports Med*, 1992, 13, 8–24.
21. Keskinen K.L., Lauri J., Komi P.V., Maximum velocity swimming: Interrelationships of stroking characteristics, force production and anthropometric variables. *Scand J Sports Sci*, 1989, 11, 87–92.
22. Keskinen K.L., Komi P.V., Stroking characteristics of front crawl swimming during exercise. *J Appl Biomech*, 1993, 9, 219–26.
23. Hollander A.P., De Groot, Van Ingen Schenau G.J., Toussaint H.M., De Best H., Peeters W. et al., Measurement of active drag during crawl arm stroke swimming. *J Sports Sci*, 1986, 4, 21–30.
24. Kolmogorov S.V., Duplishcheva O.A., Active drag, useful mechanical power output and hydrodynamic force coefficient in different swimming strokes at maximal velocity. *J Biomechanics*, 1992, 25, 311–318.
25. Seifert L., Chollet D., Allard P., Arm coordination symmetry and breathing effect in front crawl. *Human Movement Science*, 2005, 24, 234–256.

Paper received by the Editors: April 5, 2006.
Paper accepted for publication: June 4, 2007.

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HUMAN MOVEMENT
2007, vol. 8 (2), 120–123

COMPARISON OF RATE OF FORCE DEVELOPMENT OF ELBOW AND KNEE FLEXORS

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ABSTRACT
Purpose. The aim of this study was a comparison of the rate of force development (RFD) of the elbow and knee flexors. **Basic procedures.** Twenty four physical education students took part in the study. Maximum voluntary contraction (MVC) and rate of force development were measured during elbow and knee flexion (in static conditions) by means of the Biodyna dynamometer. The following rates of force development were calculated: maximum (MRFD), early (ERFD), half (HRFD), late (LRFD) and final (FRFD). **Main findings.** MRFD, ERFD, HRFD obtained during elbow flexion were significantly higher in comparison to the values obtained during knee flexion. Moreover, the results revealed strong correlations between MVC, MRFD, ERFD, HRFD, LRFD obtained during elbow and knee flexion. **Conclusions.** (1) For 0 to 50% MVC, the rate of force development for elbow flexion was higher than for the knee flexion. (2) Subjects who achieved higher level of MVC and MRFD for elbow flexion showed similar characteristics in the case of the knee flexion.

Key words: RDF, torque, elbow, knee, flexors

Introduction

The factor that determines, to a large extent, success in sports or even performance of certain tasks in everyday life, is not the value of maximum muscle force, but the ability to develop that force rapidly.

The possibility of rapid force development is often studied. The reports on that issue mainly concern the mechanisms responsible for the development of force during consecutive phases of muscular contraction [1–7]. Researchers also investigated the impact of various factors, such as training, age, lifestyle, kind of occupation, etc., on the ability of muscles to develop high force and power [8–14]. However, there are very few studies of characteristics of force development phases during muscular contractions of the various muscle groups in the same persons. The authors, therefore, decided to investigate the ability of the various muscle groups to develop force rapidly in the same people.

The aim of this study was to compare the rate of force development (RFD) of the elbow and knee flexors in the same subjects.

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Material and methods

Twenty-four young males – students of the physical education, aged 20–22 years, were examined. Characteristics of the research group are presented in Tab. 1.

The subjects were all characterized by a high level of physical fitness since they all had to take part in compulsory sports classes that were part of the curriculum. None of them, however, practiced high-performance sports. The students who participated in this experiment were healthy, which was confirmed by a physician's check. All of the subjects gave a written consent for participation in the experiment after having acquainted themselves with the procedures and methodology of the study. Moreover, the experiment had been approved by the Local Bioethics Board in Poznań (certificate 1744/03). The subjects were obliged not to use stimulants, pharmaceutics and alcohol. Whenever a subject

Table 1. Characteristic of the research group

	Age (years)	Body height (cm)	Body mass (kg)
$\bar{x}$	21.5	178	72
SD	1.0	7	10

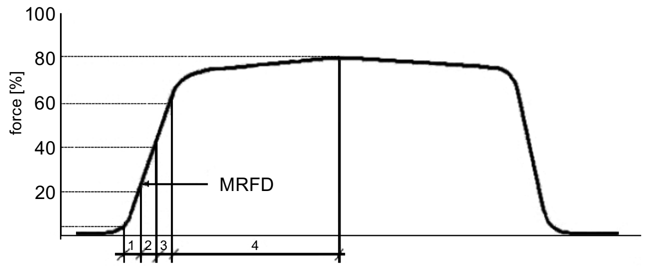
was indisposed the examination session was postponed.

The measurements were taken using the Biodyna dynamometer designed by the Institute of Aeronautics and Applied Mechanics of Warsaw University of Technology. The thickness of the shock-absorbing layer (tough rubber) of the shaft of the resistance lever was approx. 0.5 cm. The dynamometer was made of steel (body) and aluminium (levers). Measurements were taken in static conditions. In the case of the upper limb (UL) the arm was abducted by 90º from the trunk. The forearm, positioned in the transverse plain, was bent at an angle of 90º in relation to the arm. In the case of the lower limb (LL), the thigh was bent by 90º in relation to the trunk and the shin also by 90º in the sagittal plane in relation to the thigh.

The students under study participated in two pilot sessions, during which they learnt how to react properly to the following command and contract and relax muscles quickly: "Attention, after a beep press against the lever using highest possible force and relax the muscles as quickly as possible after the second beep". After the pilot sessions, each of the students took part in four measuring sessions, out of which two measured the isometric contraction of the flexors of the upper limb and the other two of the lower one. During a single session, each subject developed the maximum isometric force five times for 2–3 s. The intervals between the sessions lasted at least 48 h and 2 min between the consecutive measurements during a session. Each time before the measurement the trunk and limbs were stabilized in order to prevent action of undesired muscle groups.

Each test included a read-out of the peak torque (MVC) of the elbow and knee flexors and the rate of the peak torque development (further called the rates of force development):

1. MRFD in relation to MVC in 5 ms (%F/5ms);
2. ERFD percent of force development (from 5% to 20% of MVC) in relation to MVC in 5 ms (%F/5ms);
3. HRFD percent of force development (from 20% to 50% of MVC) in relation to MVC in 5 ms (%F/5ms);
4. LRFD percent of force development (from 50% to 80% of MVC) in relation to MVC in 5 ms (%F/5ms);
5. FRFD percent of force development (from 80% to 100% of MVC) in relation to MVC in 5 ms (%F/5ms).



1 – phase of early force development (an increase of force from 5% to 20% of MVC), in which ERFD is observed
2 – phase of half force development (an increase of force from 20% to 50% of MVC), in which HRFD is observed
3 – phase of late force development (an increase of force from 50% to 80% of MVC), in which LRFD is observed
4 – phase of final force development (an increase of force from 80% to 100% of MVC), in which FRFD is observed
MRFD – maximum rate of force development

Figure 1. The rate of force development in time

The parameters listed above are presented in Fig. 1 on the force-time curve (F-t).

The rates of force development are presented as relative values (%F/5ms). Such a way of expressing the rate of force development used by many researchers [3, 6, 15] enables avoiding the impact of the force of muscles (resulting from a disproportion of the size of the muscle groups examined) on the rate of its development.

Basic statistical calculations were made: mean arithmetic values ($\overline{x}$) and standard deviation (SD). Significance of differences was assessed using the Student's t-test – $p \leq 0.05$ was recognized as a statistically significant difference. Correlation coefficients were calculated in order to evalute the strength of relationships between the analyzed parameters – $p \leq 0.05$ was recognized as a statistically significant value.

Results

The values of MVC and rates of force development are presented in Tab. 2.

Table 2. The values of MVC and rates of force development (RFD) during the isometric contractions of the upper limb (UL) and lower limb (LL) flextion

Parameter	UL	LL
MVC (Nxm)	80 ± 15*	118 ± 33
MRFD (%F/5ms)	6.57 ± 2.47*	5.10 ± 1.80
ERFD (%F/5ms)	3.97 ± 1.92*	2.38 ± 0.77
HRFD (%F/5ms)	4.86 ± 1.77*	3.26 ± 1.28
LRFD (%F/5ms)	1.83 ± 0.96	1.63 ± 0.53
FRFD (%F/5ms)	0.11 ± 0.04*	0.21 ± 0.12

* statistically significant difference at the level of $p < 0.05$

The peak torque achieved during knee flexion was significantly higher than the peak torque achieved during elbow flexion (Tab. 2).

The rate of force development expressed by gradients: maximum, early and half rate of force development during elbow flexion was significantly higher in comparison to the knee flexion. The differences in the rate of force development between the elbow and knee flexion recede in the consecutive, late phase of force development – LRFD did not differ between elbow and knee flexion. The last phase showed a different course of force development in the muscle groups under examination – FRFD achieved during elbow flexion was significantly lower than that achieved during knee flexion.

The coefficients of correlation for the peak torque values obtained during elbow and knee flexion indicate that the students with high MVC during elbow flexion also achieved high MVC during knee flexion. This correlation also applies to the rate of force development: MRFD, ERFD, HRFD, LRFD (Tab. 3).

Table 3. Correlation coefficients between the analyzed parameters obtained during the isometric contractions of the elbow and knee flexion

Parameter	Correlation coefficient
MVC (Nxm)	0.68*
MRFD (%F/5ms)	0.46*
ERFD (%F/5ms)	0.41*
HRFD (%F/5ms)	0.59*
LRFD (%F/5ms)	0.55*
FRFD (%F/5ms)	0.17

* statistically significant correlation at the level of $p < 0.05$

Discussion

The rates of force development observed during elbow and knee flexion in the first two phases (early and half) differed significantly ($p \leq 0.05$). During the elbow flexion the MRFD, ERFD and HRFD were significantly higher than during the knee flexion. The higher rate of force development during the elbow flexion may arise from the fact that the contraction of the muscle increases quicker in shorter muscle fibers [16]. Moreover, the rate of force development is determined, to a large extent, by the fiber composition of a given muscle [17]. Although, this study did not evaluate the fiber composition of muscles, Grimby and Saltin [18] and Johnson et al. [19] claim that the elbow flexors contain approx. 53% of type II fibers, whereas the knee flexors only 33%. At the same time Mero et al. [20] confirms that muscles containing more type II fibers achieve higher MRFD values, which, in reference to this study, shows that the elbow flexors contain more type II fibers in comparison to the knee flexors. Rates of force development higher from 0 to 50% MVC for the elbow flexion can result from cellular mechanisms as well as from the fiber composition of the muscle groups examined.

The rate of force development, especially up to the point of reaching 50% of MVC, is determined, to a large extent, by the speed of transition of the crossbridge from the weak to strong binding state and myosin ATPase activity [15]. Both the speed of transition and the myosin ATPase activity is higher in the type II fibers, so those factors can determine the higher rates of force development in the initial phases of voluntary muscle contraction during elbow flexion. Moreover, the rate of force development can be influenced by the level coactivation of the antagonistic muscle groups. According to Klein [21] the level of coactivation of the triceps brachii during elbow flexion is approx. 10% [21], whereas for the thigh quadriceps during knee flexion it is approx. 5% [22]. Lack of differences in the consecutive late phase of force development and higher rate in the final phase in the muscles of the lower limbs can indicate the diversity of factors that influence the rate of force development in the later phases. It is assumed that the rate of force development during the second half of voluntary contraction is determined by the change of motor unit firing rate of already recruited motor units [4, 23].

The obtained results allow us to claim that the persons characterized by a high rate of force development during elbow flexion also achieve high development rate during knee flexion. This was confirmed by the calculated correlation coefficients; persons with high MRFD, ERFD, HRFD, LRFD values during elbow flexion achieve high values of those parameters during knee flexion. Therefore, one can assume that the ability of rapid force development is not a local capacity, but a global one that applies to majority of the muscle groups, which was confirmed by Patton [24].

It was observed that the persons who achieve high peak torque values during elbow flexion also achieve higher peak torque during knee flexion. Those correlations most probably result from the fiber composition of the muscles examined as was mentioned by Johnson et al. [19], who indicated that the people with significant content of type II fibers in some of their muscles also have more of those fibers in the other muscles of their body.

Conclusions

1. The rate of force development in the 0–50% MVC range observed during elbow flexion was significantly higher in comparison to the knee flexion.

2. People who had high MVC values and rates of force development during elbow flexion were characterized by high MVC and force development rates of the lower limbs' muscles.

References

1. Ashley C.C., Lea T.J., Mulligan I.P., Palmer R.E., Simnett S.J., Activation and relaxation mechanism in single muscle fibres. In: Sugi H., Pollock G. (eds.), Mechanism of Myofilament Sliding in Muscle Contraction. Plenum Press, New York 1993, 97–115.
2. Fitts R.H., Cellular, molecular, and metabolic basis of muscle fatigue. In: Rowell L.B., Sheperd J.T. (eds.), Handbook of physiology. Section 12. Exercise: regulation and integration of multiple systems. Oxford University Press, New York 1996, 1151–1183.
3. Jaskólska A., Naczk M., Adach Z., Kisiel K., Brzenczek W., Jaskólski A., The influence of muscle contractile properties on force development and relaxation during maximal voluntary contraction. *Physical Education and Sport,* 2003, 1, 31–43.
4. Kukulka C.G., Clamann H.P., Comparison of the recruitment and discharge properties of motor units in human brachialis biceps and adductor pollicis during isometric contractions. *Brain Res*, 1981, 219, 45–55.
5. Metzger J.M., Moss R.L., Calcium-sensitive cross-bridge transitions in mammalian fast and slow skeletal muscle fibers. *Science*, 1990, 247, 1088–1090.
6. Naczk M., Diversity of force development phase parameters depending on maximal rate of force development [in Polish]. Master's dissertation, IWF Gorzów Wielkopolski, 2000.
7. Szczęsna D., Guzman D., Miller T., Zhao J., Farokhi K., Ellemberger H. et al., The role of the four Ca^{2+} binding sites of troponin C in the regulation of skeletal muscle contraction. *J Biol Chem*, 1996, 271, 8381–8386.
8. Aagaarg P., Simonsen E.B., Andersen J.L., Magnusson P., Dyhre-Poulsen P., Increased rate of force development and neural drive of human skeletal muscle following resistance training. *J Appl Physiol*, 2002, 93, 1318–1326.
9. Adach Z., Force-velocity features characteristic of chosen muscles groups in different age men compared to anaerobic phosphagenic level. [in Polish]. AWF, Poznań 2002.
10. Barry B.K., Warman G.E., Carson R.G., Age-related differences in rapid muscle activation after rate of force development training of the elbow flexors. *Exp Brain Res*, 2005, 162(1), 122–132.
11. Gruber M., Gollhofer A., Impact of sensorimotor training on the rate of force development and neural activation. *Eur J Appl Physiol*, 2004, 92(1–2), 98–105.
12. Izquierdo M., Ibanez J., Gorostiaga E., Garrues M., Zuniga A., Anton A. et al., Maximal strength and power characteristics in isometric and dynamic actions of the upper and lower extremities in middle-aged and older men. *Acta Physiol Scand*, 1999, 167(1), 57–68.
13. Norkowski H., Krawczyk K., Anaerobic capacity characteristic of different active level students [in Polish]. *Physical Education and Sport*, 2001, 4, 469–474.
14. Suetta C., Aagaard P., Rosted A., Jakobsen A.K., Duus B., Kjaer M. et al., Training-induced changes in muscle CSA, muscle strength, EMG, and rate of force development in elderly subjects after long-term unilateral disuse. *J Appl Physiol*, 2004, 97(5), 1954–1961.
15. Wiles C.M., Young A., Jones D.A., Edwards R.H., Relaxation rate of constituent muscle-fibre types in human quadriceps. *Clinical Science*, 1979, 56, 47–52.
16. Edgerton V.R., Roy R.R., Gregor R.J., Rugg S.G., Morphological basis of skeletal muscle power output. In: Jones N.L., McCartney N., McComas A.J. (eds.), Human muscle power. Human Kinetic, Champaign 1986, 43–64.
17. Burke R.E., Motor units anatomy, physiology, and functional organization. In: Peachy L.D. (ed.), Handbook of Physiology. Section 10. Skeletal muscle. The American Physiological Society, Bethesda 1983, 345–422.
18. Grimby G., Saltin B., The ageing muscle. *Clinical Physiology*, 1983, 3, 209–218.
19. Johnson M.A., Polgar J., Weightman D., Appleton D., Data on the distribution of fibre types in thirty-six human muscles: An autopsy study. *J Neurol Scien*, 1973, 18, 111–129.
20. Mero A., Luhtanen P., Viitasalo J.T., Komi P.V., Relationship between the maximal running velocity, muscle fiber characteristics, force production and force relaxation of sprinters. *Scand J Sport Sci*, 1981, 123, 553–564.
21. Klein C.S., Rice C.L., Marsh D., Normalized force, activation, and coactivation in the arm muscles of young and old men. *J Appl Physiol*, 2001, 91, 1341–1349.
22. Macaluso A., Nimmo M.A., Foster J.E., Cockburn M., McMillan N.C., De Vito G., Contractile muscle volume and agonist–antagonist coactivation account for differences in torque between young and older women. *Muscle & Nerve,* 2002, 25, 858–863.
23. Oishi K., Nigornikowa T., Time to peak force and force developing speed during fast maximal and submaximal isometric voluntary contractions. *Ann Physiol Anthrop*, 1988, 7, 5–14.
24. Patton J.F., Upper and lower body power: comparison between biathletes and control subjects. *Int J Sports Med,* 1987, 8, 94–98.

Paper received by the Editors: October 23, 2006.
Paper accepted for publication: August 24, 2007.

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HUMAN MOVEMENT
2007, vol. 8 (2), 124–127

ADAPTATION PROCESS IN SWIMMING INITIATION: THE LEARNING TO SWIM PROJECT

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ABSTRACT
Purpose. Swimming is a worldwide sport. However, its teaching–learning process is mainly centered on style, leaving aside the most essential phase – the adaptation. The aim of this paper is to describe experience gained within the Learning to Swim Project (LSP), a teaching and research initiative at Physical Education Faculty/UNICAMP, based on consideration of the adaptation process and on teaching through movements and easy execution. **Basic procedures.** Each class lasts 60 min, twice a week and is divided into three stages: warming up, main session, and relaxation. Even the main session is composed of specific exercises such as the control of the body, floating and propulsion, among others, without abandoning the adaptation principles. The classes include educational and corrective exercises and games. The program is very flexible, and varies according to the assimilation capacity of the students. **Main findings and conclusions.** The results indicate that our approach can be considered efficient, since it promotes a fast and adequate learning process.

Key words: learning, sport, physical activity, water exercise

Introduction

Swimming is an ancient sport which involves people of different ages for several reasons, such as competition or due to the benefits one gets from swimming activities. Thus swimming is popular in many places, e.g. clubs, clinics and academies. However, most initiatives seem to place more emphasis on the fast learning of several swimming strokes, leaving aside an essential phase, that is the "adaptation". Learners are usually acquainted with stereotyped movements consisting of specific technical exercises before having any contact with the several forms of locomotion, interaction and problem solving. The aim of this work is not to report on the effectiveness for comparison purposes, but to describe our experience gained from teaching adults in swimming classes based on consideration of the adaptation process, which has been ignored by most earlier studies.

But, what is "adaptation"? To develop adaptation is to develop adjustment and accommodation. Adaptation has been the precursor of the initiation level, which gives priority to the acquisition of an ample motor repertoire, as well as the control of swimming gestures. It is composed of five steps: initial contact, floating, respiration, propulsion and elementary diving.

Initial contact promotes an "intimate relationship" between the water and the future swimmer, who desires to see and to feel the water [1]. The primary objective is to eliminate muscle rigidity, usually due to fear. In other words, the aim is to give the beginner the sensation of well being, confidence, and to acquire the skills for efficient movement in water [2].

Floating is the ability to maintain the body partially on the surface. It is linked to muscle relaxation, which is associated with a good mental state, and is absent in any situation involving anxiety [3]. However, different authors mention other factors, in particular physiological ones (such as the percentage of body fat), and the amount of air in the lungs as being responsible for the efficiency of or ability to float [4].

Efficient respiration is essential for comfort in the aquatic environment. It is developed only after an adaptation period, because both mouth and nose are in the water. In this situation, inhaling should be performed through the mouth and exhaling through the mouth and

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nose for a longer period than inhaling with the movement of the upper limbs [2].

Propulsion, which is the joint movement of the upper and lower limbs, is essential for execution of all swimming strokes. The body must be extended in order to get a good slide, which is reached with the head slightly raised in relation to the hip [5].

Elementary diving involves different methods of entering the water, from the simplest, such as jumping from standing or sitting, to those used by high-level swimmers. This gradual didactics, which involves several phases of learning, contributes significantly to better assimilation during classes, and throughout the training period [6, 7].

Materials and methods

The objective of the Learning To Swim Project put forward by the Physical Education Faculty/UNICAMP is to place different emphasis on the adaptation stage compared to similar projects. Many swimming programs follow models with detailed techniques used in specific training for competition in order to achieve faster learning. They apply exercises similar to those in specific strokes, without considering the methodology used in the aquatic environment, general movements, motivation, and communication. This paper presents the aspects related into initiation to swimming based on recent evaluation of this program (Tab. 1) [8].

Tab. 2 presents frequency distributions of some interesting variables for a training group, which include: gender, duration of regular physical practice, type of preferred sport, tobacco consumption, daily coffee drinking habits, current disease.

As methodological-theoretical background, we adopted a synthetic pedagogic practice based on teaching through overall movements and easy execution [9]. The chosen learning process comprised educational and corrective exercises and games. This enables better interaction, since the students get more involved in playful activities, leaving aside their anxiety due to the new environment [10]. This leads to a more pleasant experience, which is essential for beginners. In addition, it increases the interest in practicing the exercises, and avoids quitters who lack motivation due to repetitive exercises.

The educational exercises lead to a repertoire of movements which can be assimilated and incorporated into the particular swimming strokes. In this way, the students can "construct" the repertoire step by step, and can take corrective procedures to avoid any deficiencies in their mechanical movements.

Table 1. Initiation classes of the Learning to Swim Project (LSP)

Semester	Number of classes		Percentage of initiation classes (B/A%)
	LSP (A)	Initiation (B)	
1st	14	6	42.86
2nd	15	7	46.66
3rd	16	6	37.50
4th	12	6	50.00
5th	14	6	42.86
Total	71	31	43.66

Table 2. Frequency distribution of some variables characteristic of a LSP training group

Variable	Frequency	
	Absolute	Relative
Gender		
Male	80	44.1
Female	101	55.9
Regular physical activity		
Less than 1 year	79	43.6
1 to 3 years	49	27.1
More than 3 years	53	29.3
Type of preferred sport		
Individual	78	43.1
Collective	22	12.2
None	81	44.7
Daily use of tobacco		
None	162	89.5
Less than 1 packet	15	8.3
1 packet	3	1.6
More than 1 packet	1	0.6
Daily coffee consumption		
None	73	40.3
Less than 1 cup	87	48.1
1 cup	16	8.8
More than 1 cup	5	2.8
Current disease		
Yes	144	20.4
No	37	79.6
Total	181	100.0

The classes last for 60 min each, 2–3 times a week and are divided into three stages: warming up, the main session, and relaxation. The first stage prepares the body for the subsequent physical activity and is composed of general exercises and very diversified stretching. The exercises begin out of the water but continue in the water, with some games, aerobic circuits, and some sequences of hydrogymnastic movements. The main session includes specific exercises such as control of the body, floating and propulsion, among others, without abandoning the principles of adaptation. The relaxation, in the last part of the class, includes recreational games, massage, and different forms of stretching, such as those accomplished by pairs of students. The aim is to bring the body back to its initial physical condition and allow the student to return to everyday duties.

The program adopted in the project guarantees emphasis on the adaptation period in the water environment with more than 50% of the total content. However, the program is flexible, and varies according to the assimilation capability of the students. Tab. 3 provides a general overview of classes following a 16 weeks' program.

Table 3. General overview of the classes during the swimming initiation course, developed within the Learning to Swim Project (LSP), PEF/UNICAMP

Week	Class
1	Adaptation to the aquatic environment (entering the water); immersion, integration games
2	Adaptation; games; moving around
3	Initial respiration activities
4	Moving around; respiration; floating
5	Floating in dorsal, ventral and lateral decubitus; sliding
6	Dorsal and ventral sliding on the surface; recuperation exercises in the prone position (ventral decubitus) and the supine position (dorsal decubitus)
7	Respiration (frontal/lateral); propulsion
8	Floating; propulsion with the upper and lower limbs; sliding with impulse
9	Exploration of the bottom of the pool; propulsion with the lower limbs; introduction to the crawl stroke
10	Propulsion with the upper limbs; crawl arm; introduction to diving
11	Bilateral respiration; crawl; diving
12	Synchronization of the crawl stroke
13	Introduction to the backstroke
14	Backstroke; crawl; diving
15	Synchronization of the backstroke; crawl
16	Educational activities using the crawl and backstroke

The performance of the coach is fundamental to transmit confidence to the beginners and provide a variety of experiences, which makes the students confident about their own body and motor reaction in the pool [11].

Special attention is given to the adaptation of every student and the execution of the swimming movements in order to promote correct learning of each stroke. Each coach is trained to identify erroneous movements and correct them.

Alternative materials such as floaters, boards, and swim fins are used extensively, since they diversify the class activities, which became more attractive with new forms of interaction.

The program methodology involves oral, visual and tactile resources. The following steps are adopted to teach swimming: verbal commands, before or after their description; demonstration of the commands; and kinesthesia, since the touch awakens the body to activities. In addition, filming is used to visualize the movements and aid in further correction.

Results and conclusions

During this research some relevant issues have arisen, such as:

1. The use of the general-to-specific perspective: general "issues" (such as adaptation to the water environment) precede more specific aspects (such as the swimming technique). Thus, only after assimilation of adaptive issues are the crawl and backstroke strokes considered. Afterwards, teaching sequences are adopted for each stroke, without abandoning the main purpose of the initiation, which involves acquisition of motor skills specific to the aquatic environment.
2. The incorporation of playful activities during the learning process: this makes the students more confident when exposed to new challenges.
3. The teachers were surprised by the way and the frequency the students showed their motor development acquired during the classes.
4. It is known that adaptation, when well developed, is able to promote interaction and harmony between

the practitioner and the environment. This contributes to the learning process of the standard motor movements. In this period the sensation of fear is removed from those with no previous swimming experience.

5. It is also observed that the better the experience at this learning stage, the better the possibilities of satisfaction in this sport during leisure time.

In summary, this methodology may be considered compatible with the expectations of the local community since it is efficient and provides fast, solid learning. This is supported by the fact that the number of initiation classes offered by the project has been increased. The practice of this activity under the guidance of the Physical Education Faculty also contributes to knowledge of the area, in this case to sport science.

Acknowledgements
The authors acknowledge their intellectual debt to Prof. Fabrício Boscolo Del Vecchio for his careful contribution to the bibliographic references.

References

1. Austswim Inc., Teaching swimming and water safety. Human Kinetics, Champaign 2001.
2. Thomas D.G., Swimming: steps to success. Human Kinetics, Champaign 2005.
3. Thomson H., Kearns A., Petticrew M., Assessing the health impact of local amenities: a qualitative study of contrasting experiences of local swimming pool and leisure provision in two areas of Glasgow. *J Epidemiol Community Health*, 2003, 57(9), 663–667.
4. Kjendlie P.L., Ingjer F., Stallman R.K., Stray-Gundersen J., Factors affecting swimming economy in children and adults. *Eur J Appl Physiol*, 2004, 93(1–2), 65–74.
5. Rouhana J., Ferry F., Toussaint L., Boulinguez P., Knowledge of results and explicit instruction: efficiency of learning the crawl stroke in swimming. *Percept Mot Skills*, 2002, 5(3), 895–896.
6. Coleman R., Learn to swim: learn to swim aids. *Swimming in Australia*, 2002, 18(5), 64–65.
7. D'Arripe-Longueville F., Gernigon C., Huet M.L., Cadopi M., Winnykamen F., Peer tutoring in a physical education setting: influence of tutor skill level on novice learners' motivation and performance. *J Teach Phys Educ,* 2002, 22(1), 105–123.
8. Leo C.C.C., Galdi E.H.G., Padovani C.R., Gonçalves A., Vilarta R., Análise do perfil da demanda do Projeto Aprender a Nadar da FEF/ Unicamp [in Portuguese]. *Edição Especial da Revista Brasileira de Ciência e Movimento*, 2002, 10(4), 275.
9. Fischman M.G., Comparison of two methods of teaching the breaststroke to college-age nonswimmers. *Percept Mot Skills*, 1995, 61(2), 459–462.
10. Moore M., Moore S., Sharks and minnows: sharpen the teeth in your learn to swim program. *Parks Recreation*, 1997, 32(2), 44–47.
11. Harmer J., Lowden S., Marks K., Richter K., Kilpatrick J., Maclean J., et al., Application of principles of movement in water. In: Austswim Inc., Teaching swimming and water safety. Human Kinetics, Champaign 2001, 73–95.

Paper received by the Editors: December 26, 2005.
Paper accepted for publication: October 23, 2007.

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HUMAN MOVEMENT
2007, vol. 8 (2), 128–135

STRUCTURE AND DYNAMICS CHARACTERISTICS OF TRAINING LOADS IN DIRECT INITIAL PREPARATION OF SWIMMERS

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ABSTRACT
Purpose. The final stage of preparations for competitions has a special subperiod called direct initial preparation (DIP). The most significant goal of DIP is maintaining proper proportions between the intensity and volume of exercise loads. The purpose of the present study was to find the correlations between the volume and intensity of the training loads and their impact on the sports results. **Basic procedures.** Training work performed by a female Olympic swimmer was subjected to analysis. The swimmer completed a 6 week long DIP preparing her for the start in European Championship in Valencia at a 25 m pool. The analysis of training loads was accomplished based on the method developed at the Department of Theory of Sport in Warsaw. The printout of results recorded by means of Omega timing device has been used for analysis of starting loads. **Main findings.** The DIP subperiod is the most important link in the chain of starting preparation and achieving significant results in the main events. However, swimming training and its effectiveness are not determined only by proper use of training and starting loads, but are also affected by other elements of the training process, such as: technical support of water training and gym training, periodical diagnostics of the swimmers condition as well as during the individual training units, proper diet and supplementation enhancing the process of biological regeneration. **Conclusions.** Adequate proportions between volume and intensity of training loads, properly distributed throughout the phases of DIP, translate into the shaping of the best starting performance. The structure and volume of the training in DIP should be planned on the basis of post-training assessment of effects.

Key words: training loads, swimming, DIP, analysis of sport results

Introduction

Training is a continuous process of long-term and specific exercise adaptation of the body. The basic factors that affect the effectiveness of training and development of a sportsman are the training loads [1].

The issue of training and starting loads is one of the least explored problems of the theory of training. Lack of papers concerning work of outstanding coaches, deprives other less experienced instructors of the information on reliable ways of achieving success – in consequence, successive generations of coaches use the method of "trial and error" in their instruction work [2].

In recent years, training and starting loads have been exceptionally high. The increasing number of swimming championship competitions in the calendar of the World Federation of Swimming and the European Swimmers League has complicated the structure of macro- and microcycles, and training units. It became necessary for swimming coaches to establish long-term training schedules with particular consideration of preparation for championship competitions.

In the final stage of preparations for competitions, the main task of a coach is to increase the achieved level of special training and ensure top performance during the competition. This stage has a special subperiod called direct initial preparation (DIP). The most significant goal of DIP is maintaining proper proportions between the intensity and volume of exercise loads [3–5]. This provides a real capacity for individualization of training and streamlining/rationalization of the training loads, so that they become adequate for the present condition of the competitor. In swimming, in the case of top-class competitors preparing for a championship contest, DIP takes from 6 to 9 microcycles that are divided to 3 phases (accumulation, intensification and transformation). At that time, training should be based on starting exercises and special exercises that correspond with the former in terms of functionality and structure.

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While planning DIP, one should take into account: date of qualification for the main competition, date and duration of the main competition, number of starts in the season, competitor's level of training and also the functional capacity of a competitor before commencement of every successive training unit [6, 7].

The experience gained during preparation of the top-class competitors, seeking criteria for recording and analysis of the training work performed and using available papers should contribute to achieving better results by swimmers. The authors using up-to-date knowledge have made an attempt at finding the correlations between the volume and intensity of the training loads applied in the final 6 microcycles before the start in the main competition and their impact on the sports results.

Material and methods

The study comprised a female Olympic swimmer with a long training experience, who has been achieving top-class results. She represented a very small group of swimmers who achieved their best results as adults (25–31 years).

The swimmer under examination had the following life records in a 25 m pool:

- 100 m breaststroke 1:07.71 (European Championship Sheffield '98),
- 200 m breaststroke 2:23.94 (Polish Senior Championship Koszalin '98).

Training work performed during DIP in a 25 m pool from October 30, 2000 to December 12, 2000 was subjected to analysis. During this period the swimmer completed a six week long DIP, preparing her for the start in European Championship in Valencia in a 25 m pool (where she won a gold medal at the finish of her career).

Training took place:

- at pool – from 6^{00} to 8^{30} and from 17^{00} to 19^{30},
- at gym – from 16^{00} to 17^{00}.

The monitoring of training and starting loads was performed during:

- trainings at the club,
- national and international competitions.

A method developed at the Department of Theory of Sport in Warsaw was used for the purpose of analysis of training loads. It takes into account two directions of impact on the body:

- kind of preparation (so called information area),
- impact of training loads on the biological mechanisms (so called energy area).

The analysis of starting loads was accomplished based on the printouts of results recorded on the protocols by means of Omega timing device that performs electronic registering of timing during a swimming competition at a 25 m pool.

The research used the following instruments:

- heart action analyser Sport Tester PE 4000 produced by Polar Sport,
- Sony stopwatch for measuring time and frequency,
- Accusport miniphotometer for measuring lactic acid level produced by Boehringer Mannheim,
- a computer kit with the following software installed: Ms Excel, Access, Word.

Results

DIP was accomplished in the following period from October 30, 2000 to December 12, 2000 and covered 38 training days, which were divided into:

- accumulation from October 30, 2000 to November 19, 2000 – 18 training days,
- intensification from November 20, 2000 to December 3, 2000 – 11 training days,
- transformation from December 4, 2000 to December 12, 2000 – 9 training days.

During that period the swimmer attended 62 trainings in water and 33 at gym (Tab. 1).

Table 1. The number of trainings accomplished during DIP phases

	Accumulation		Intensification		Transformation		Total	
	Water	Gym	Water	Gym	Water	Gym	Water	Gym
Morning training	17	8	12	8	6	0	35	16
Afternoon training	14	10	10	5	3	2	27	17
Total	31	18	22	13	10	2	62	33

Table 2. Distribution of the training work in water in DIP phases

Accumulation

Kind of work (km) \ Date	30.10	31.10	2.11	3.11	4.11	6.11	7.11	8.11	9.11	10.11	11.11	13.11	14.11	15.11	16.11	17.11	18.11	19.11	Total	Intensity (km/day)	% of total DIP work
D	6.2	4.0	11.4	5.0	9.2	6.2	0	0	9.0	0.7	8.3	8.2	1.5	7.5	8.4	4.9	0.7	0.6	91.8	4.3	76.1
S	1.8	4.2	3.5	2.8	3.3	2.3	0	0	4.1	3.5	5.7	1.6	3.8	7.3	2.0	1.4	0.5	0.6	48.4	3.5	49.9
Total	8.0	8.2	14.9	7.8	12.5	8.5	0	0	13.1	4.2	14.0	9.8	5.3	14.8	10.4	6.3	1.2	1.2	140.2	7.8	64.4

D – directed tasks, S – special tasks

Intensification

Kind of work (km) \ Date	20.11	21.11	22.11	23.11	24.11	25.11	27.11	28.11	30.11	2.12	3.12	Total	Intensity (km/day)	% of total DIP work
D	2.3	1.3	1.8	2.1	2.3	1.2	2.2	1.7	1.1	1.0	1.0	18.0	1.8	14.9
S	1.7	3.3	3.0	2.9	2.3	2.9	4.1	4.7	3.6	0.8	0.8	30.1	3.0	31.0
Total	4.0	4.6	4.8	5.0	4.6	4.1	6.3	6.4	4.7	1.8	1.8	48.1	4.8	22.1

D – directed tasks, S – special tasks

Transformation

Kind of work (km) \ Date	4.12	5.12	6.12	7.12	8.12	9.12	10.12	11.12	12.12	Total	Intensity km/day	% of general DIP work
D	0.7	0.3	0.7	1.3	2.1	1.3	1.4	1.7	1.3	10.8	1.0	9.0
S	1.4	1.0	2.6	1.7	2.9	2.9	2.0	2.3	1.7	18.5	1.9	19.1
Total	2.1	1.3	3.3	3.0	5.0	4.2	3.4	4.0	3.0	29.3	2.9	13.5

D – directed tasks, S – special tasks

DIP in total

Kind of work (km)	Total	Intensity (km/day)	% of total DIP work
D	120.6	3.2	55.4
S	97.0	2.5	44.6
Total	217.6	5.7	100.0

D – directed tasks, S – special tasks

Table 3. The structure of training loads (VDS) in DIP phases with regard to energetic level

DIP phase	VDS1	VDS2	VDS3	VDS4	VDS5	VDS1–5
Accumulation	3:30.03	6:59.09	7:58.37	1:56.23	0:52.18	21:16.30
Intensification	3:14.10	6:11.02	5:32.35	4:50.15	0:24.00	20:12.02
Transformation	2:22.08	4:20.30	2:50.18	1:05.10	1:20.43	11:58.49
Total	9:06.21	17:30.41	16:21.30	7:51.48	2:37.01	53:27.21

V – versatile, D – directed, S – special, 1, 2, 3, 4, 5 – intensity grade

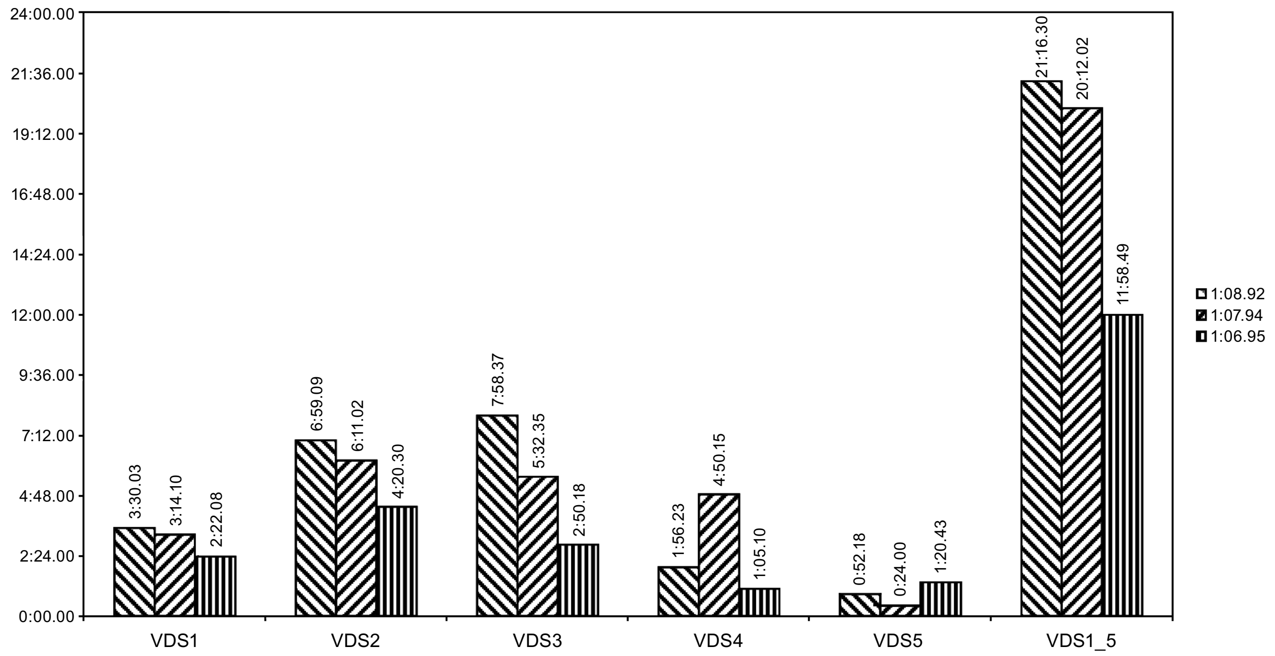

Figure 1. Total training work including 5 intensity levels performed between consecutive competitions during DIP for the European Championship in Valencia 2000

During trainings in water the swimmer swam 217.6 km, including 120.6 km of directed tasks and 97.0 km of special tasks (Tab. 2).

Total duration of the entire DIP was 53 h 27 min 21 s (Tab. 3).

For the first 18 training days of DIP, the swimmer was accomplishing the phase of accumulation. The training work was characterized by a gradual increase of volume at low intensity of burden. The first "volume" microcycle was characterized by a low intensity at relatively high volume.

The two successive microcycles had an impact capacity and were characterized by an increased intensity of training loads in water as well as at gym (in the first microcycle the swimmer did not attend training for 2 days due to subfebrile temperature). The total training work duration in water and at gym was 21 h 16 min 30 s and the lower energetic level exercising was dominant (2nd intensity grade – 6 h 59 min 9 s and 3rd intensity grade – 7 h 58 min 37 s) (Tab. 3, Fig. 1).

During this phase the exercises performed were as follows: mixed exercises (7 h 21 min 42 s), aerobic exercises 5 h 8 min 45 s (Tab. 5, Fig. 3) and versatile ones that had the largest share of sustaining aerobic exercises (1 h 28 min 50 s), shaping aerobic exercises (1h 35 min 20 s) and anaerobic exercises (1 h 14 min 13 s) (Tab. 4, Fig. 2).

Large amounts of versatile anaerobic exercises were connected with intense strength training at gym with the use of training equipment. Special exercises were performed regardless of the energetic grade to a very small degree – they lasted 1 h 33 min 22 s in total (Tab. 6, Fig. 4).

Special measures were used only for sustaining and regeneration of specific motor-muscular coordination and effort capacity. During that phase the swimmer swam 140.2 km in total – which was 64.4% of the total

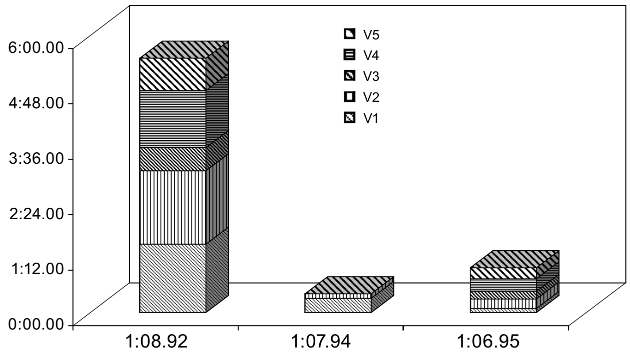

Figure 2. Size and structure of versatile work performed between consecutive competitions during DIP for the European Championship in Valencia 2000

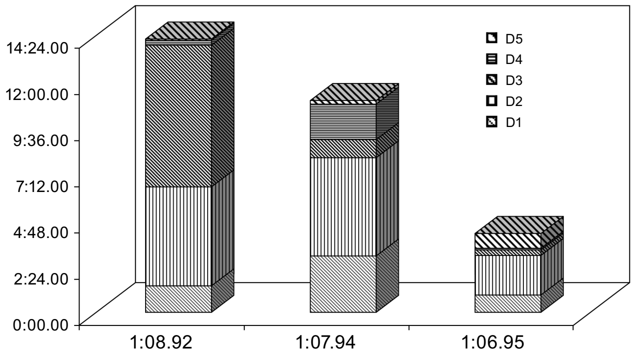

Figure 3. Size and structure of directed work performed between consecutive competitions during DIP for the European Championship in Valencia 2000

Table 4. Structure of versatile training loads (V) in DIP phases

DIP phase	V1	V2	V 3	V4	V5	V1–5
Accumulation	1:28.50	1:35.20	0:30.10	1:14.13	0:42.00	5:30.33
Intensification	0:18.25	0:06.00	0:00.00	0:00.00	0:00.00	0:24.25
Transformation	0:05.13	0:12.20	0:10.00	0:16.20	0:14.16	0:58.09

1, 2, 3, 4, 5 – intensity grade

Table 5. Structure of directed loads (D) in DIP phases

DIP phase	D1	D2	D3	D4	D5	D1–5
Accumulation	1:22.30	5:08.45	7:21.42	0:15.27	0:04.11	14:12.35
Intensification	2:55.45	5:06.23	0:56.38	1:50.42	0:11.09	11:00.37
Transformation	0:53.55	2:03.24	0:17.23	0:05.05	0:46.08	4:05.55

1, 2, 3, 4, 5 – intensity grade

Table 6. Structure of special loads (S) in DIP phases

DIP phase	S1	S2	S3	S4	S5	S1–5
Accumulation	0:38.43	0:15.04	0:06.45	0:26.43	0:06.07	1:33.22
Intensification	0:00.00	0:58.39	4:35.57	2:59.33	0:12.51	8:47.00
Transformation	1:23.00	2:04.46	2:22.55	0:43.45	0:20.19	6:54.45

1, 2, 3, 4, 5 – intensity grade

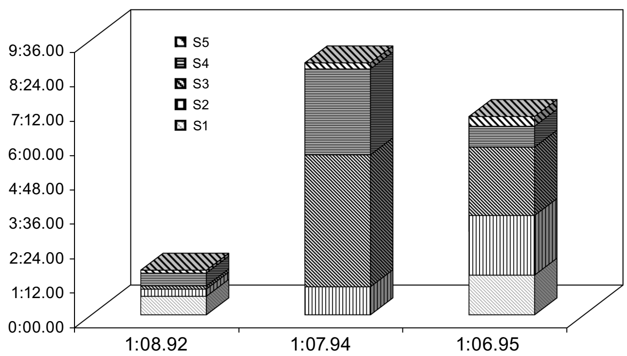

Figure 4. Size and structure of specialized work performed between consecutive competitions during DIP for the European Championship in Valencia 2000

DIP work (Tab. 2). As for water exercises, directed exercises were dominant, which were aimed at universal preparation of the swimmer and creating of a basis for successive work on the factors that directly affect the results. What summed up the training work in the accumulation phase was a start in Polish GP cycle competition in Gryfino, during which the swimmer, after a large exercising volume, had timing that was significantly worse than her life records (Tab. 7).

After the competition, on November 20, 2000, the next DIP phase began – intensification. The main goal of this 11 day long phase was to create conditions for further development of performance by using various means and special burdens, which are at higher intensity level. The volume of training work remained at a level similar to accumulation phase and was 20h 12min and 2 s (Tab. 3). During this phase, the intensity of training was increased, which can be illustrated by a 100% growth of the 4th intensity grade burdens (from 1:56.23 to 4:50.15) in comparison to the accumulation phase (Tab. 3). This was a result of application exercises improving force-speed parameters in water as well as gym training. Versatile exercises' volume was significantly reduced – only 24 min and 25s – and the exercises were of lower intensity grade, so called warm-up and agility exercises before entering water (Tab. 4, Fig. 2). The 3rd and 4th intensity grade breaststroke exercises were dominant (Tab. 6, Fig. 4), which were aimed at increasing the swimmers capacity for enduring high intensity burdens and technical breaststroke exercises of high intensity performed with or without gear.

During that phase the swimmer swam 48.1 km in total, including 18 km of directed exercises and 30.1 km of special exercises (Tab. 2). At the end of the intensification phase the swimmer took part in European Championship qualifying competition – Polish Senior Championship in Łódź, during which she qualified for the start at Valencia. The result she achieved – 1:07.94 – was very close to her life record, which had been 1:07.69 (Tab. 7).

The last DIP phase – transformation – to a start in the most important competition of the winter season commenced on December 4, 2000 and lasted until December 12, 2000. Volume and intensity were significantly decreased in that period. During 9 training days, the swimmer attended 10 trainings in water and 2 at gym, (Tab. 1), which was accomplished at the time of 11 h 58 min and 2s (Tab. 3).

During that period, training was aimed at direct shaping of sports performance. The swimmer accomplished special exercising tasks with regard to individual adaptation capacity and speed of restitution between the successive training units. Anaerobic, non-lactic exercises were dominant in this stage – 20 min 19 s (Tab. 6). The swimmer made lots of sprints, starts, finishes and returns with full relaxation. In order to maintain the level of preparation, the swimmer performed lots of 3rd intensity grade exercises – 2 h 22 min 55 s and 2nd intensity grade – 2 h 4 min 46 s (Tab. 6, Fig. 4).

From December 13 to 17, 2000 the swimmer was accomplishing starting microcycle, during which she performed regenerative tasks with low loading. She attended procedures ensuring full physical and psychological regeneration (massages, meetings with a psychological, relaxation and agility exercises). Majority of training units meets the starting requirements – every second training the swimmer swam 100 m breaststroke. In the remaining training units she accomplished the tasks of "feeling the water".

During the start in European Championship in Valencia, the swimmer won a gold medal in a 100 m breaststroke competition and improved her Polish record to 1:06.95 s (Tab. 8).

Table 7. List of starts of the swimmer under examination during the DIP for European Championship in Valencia 2000

	Rank of swimming competition	Place and date	Eliminations		Semifinal		Final	
			Distance, stroke and time	Place	Distance, stroke and time	Place	Distance, stroke and time	Place
1.	GP of Poland	Gryfino November 18–19, 2000	100 m breaststroke 1:08.92 s	1	–	–	–	–
			200 m medley 2:14.55 s	1	–	–	–	–
			200 m breaststroke 2:30.08 s	1	–	–	–	–
			100 m medley 1:03.27 s	1	–	–	–	–
2.	Polish Senior Championship	Łódź December 1–3, 2000	100 m breaststroke 1:09.14 s	1	–	–	100 m breaststroke 1:07.94 s	1
			200 m breaststroke 2:32.73 s	1	–	–	200 m breaststroke 2:26.12 s	1

Table 8. Starts of the swimmer under examination during 100 m breaststroke European Championship in Valencia 2000

	Eliminations December 16, 2000		Semifinal December 16, 2000		Final December 17, 2000	
	Time	Place	Time	Place	Time	Place
RT	0.79	4	0.79	1	0.76	1
50 m	32.82		32.44		31.72	
100 m	1:09.39		1:08.10		1:06.95	

RT – reaction time to the starter signal

Discussion

The tests carried out during DIP allowed the researchers to develop a broad approach to the issue of the training and starting loads that aim at the best possible preparation of the swimmers for achieving their life records.

Our findings allowed performing various comparisons of volume and structure of the training loads in the final stage of preparation for the main events of the season.

It should be emphasized that in swimming, in a year's training cycle, one needs long time to achieve the peak starting performance. Costill, Maglischo, Richardson [6] and Płatonow [5] unanimously claim that preparation of the peak sports performance requires at least 8 months. The length of that period depends on the initial level of swimmer's preparation at the onset of the successive macrocycle. The lower the initial level, the longer the time is required to shape the energetic mechanisms when intensive work is resumed.

Taking into consideration the above, the DIP period is the most important link in the chain of starting preparation and achieving significant results in the main events.

However, modern swimming training and its effectiveness are not determined only by proper use of training and starting loads. The level of achievements is also affected by other elements of the training process, such as: technical support of water training and gym training, periodical diagnostics of the swimmers condition as well as during the individual training units, proper diet and supplementation increasing the process of biological regeneration.

Conclusions

1. Accomplished training and starting loads during DIP for the European Championship in Valencia in 2000, ensured the swimmer's advancement. With a result of 1:06.95 s she beat the European Championship record and won a gold medal in 100 m breaststroke.

2. Adequate proportions between volume and intensity of training loads, properly distributed throughout the phases of DIP, translate into the shaping of the best starting performance:

a) the first phase of DIP – accumulation, is characterized by a gradual increase of volume, at low intensity of loading; the dominant exercises should be: V1, V2, V4, D2, D3 and S1;
b) the main part of DIP – intensification, is characterized by a reduction of work volume with simultaneous increase of its intensity and the following exercises should be dominant: D1, D2, D4 and S3, S4;
c) during the transformation phase, the swimmer should achieve the peak performance through reduction of duration of the training units, decrease of volume and intensity of the exercises and by performance of starting exercises of higher intensity level V5, D5, S5, which should be interwoven with the exercises from D2, S1, S2 group.

3. The structure and volume of the training loads in DIP should be planned on the basis of post-training assessment of effects of loads accomplished so far and with consideration of the qualifying competitions, number of starts, climate conditions and main event's regulations.

4. Due to the fact that during year's training cycles of top-class swimmers, the starting period is of vital importance and causes reduction of the other stages of shaping the peak performance, DIP should be used only as preparation for the main, most important events.

5. Psychological factor plays a significant role during starts in the most prestigious competitions. In the analysed case, the strong motivation of the swimmer to give the best possible performance in the last competition in her career was a tremendously important factor that helped her to achieve high result.

The above findings on the starting and training loads accomplished during DIP by the swimmer specializing in breaststroke can be a reference point for other coaches as well as for developing one's own coaching skills in order to find the optimum loading indicators for the swimming training.

References
1. Sawczyn S., Training loads in gymnastics during long training process [in Polish]. AWF, Gdańsk 2000.
2. Sozański H., Czerwiński J., Preparations for Olympic Games as an indicator of new training ideas [in Polish]. *Sport Wyczynowy*, 1998, 11–12, 13–18.
3. Bartkowiak E., Competitive swimming [in Polish]. COS, Warszawa 1999.
4. Dorywalski T., Juszkiewicz M., Lach K., Rolski Z., Lactate test as criteria of level of training and prediction of swimming result [in Polish]. *Sport Wyczynowy*, 1992, 3–4, 69–72.
5. Płatonow W.N., Professional training in swimming [in Polish]. COS RCM-SZKFiS, Warszawa 1997.
6. Costill D.L., Maglischo E.W., Richardson A.B., Swimming (Handbook of sports medicine and science). Oxford Blackwell Science, London 1992.
7. Kosmol A., Training loads in year's training cycle of Polish swimmers on different development stages [in Polish]. *Trening*, 2000, 3, 40–51.

Paper received by the Editors: July 6, 2006.
Paper accepted for publication: September 24, 2007.

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HUMAN MOVEMENT
2007, vol. 8 (2), 136–146

BERNSTEIN'S CONSTRUCTION OF MOVEMENT MODEL AND CONTEMPORARY MOTOR CONTROL AND MOTOR LEARNING THEORIES

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ABSTRACT
The paper presents Bernstein's five-level model of motor control and motor learning in humans: A – muscle tonus, B – muscle synergies, C – spatial mobility, D – complex motor performances, and E – symbolic representations of motor performances. Each level corresponds to a group of sensorimotor actions, i.e. a way of using receptors, effectors, and particular components of the central nervous system. The higher the levels, the more complex sensorimotor task it can control. Each level corresponds to its own theoretical control model: levels B and C – to Gibson's ecological theory and the Equilibrium Point Hypothesis (EPH) by Feldman; level D – to the "cybernetic" models, e.g. Schmidt's scheme. For storing and transferring information, levels A, B and C use mainly the sensory code, while levels D and E the symbolic code. The motor command delivered to a muscle has to always be expressed in the sensory code; hence in the control system it is necessary to "translate" the sensory code into symbolic one and vice versa. Consequently, it is possible to create two motor learning models: model "0", describing the circulation of sole sensory information between levels A, B and C, and model "8" assuming two circles of information exchange: lower, sensory, at levels A, B and C; and higher, symbolic, at levels D and E. In the ABC region we deal with data driven processes, for which behaviourism can serve as a theoretical basis, while the DE region features conceptually driven processes which require some cognitive explanation. Besides, in the process of motor learning an important part is played by information "chunking", necessary for transcoding. The cooperation of sensory, short-term, long-term and working memories is also of vital importance.

Keywords: motor control, motor learning, Bernstein's theory

Introduction

In 1947, Nikolai Aleksandrovitsch Bernstein presented his theory of construction of movement in his famous work *О построении движений* [1]. This title was translated into English as *The coordination and regulation of movements* [2]. It is not quite accurate because the Russian word "построение" means "construction", and not "coordination and regulation". Hence, the title should rather read "On the construction of movements". In fact, the properly formulated title – truly reflecting the meaning of the original – does not limit the book contents to mere "coordination and regulation" (i.e. control) of sensorimotor performances, but encompasses a full spectrum ("construction", i.e. both control and learning) of problems associated with human motor behaviour. Bernstein wrote his book for specialists, thus it was rather difficult to understand for non-specialists. To present his main ideas to a wider readership, he wrote a parallel, more comprehensible book entitled *О ловкости и её развитии* (*On dexterity and its development*) [3]. Unfortunately, because of the complicated fate of the book [4, 5] in Soviet Russia, it was published for the first time (in Russian) in 1991, i.e. 24 years after Bernstein's death. Five years later Mark L. Latash translated it into English [6].

The main subject of the book *О ловкости и её развитии* is the theory of motor control assuming five levels corresponding to definite parts of the central nervous system and responsible for particular categories of motor activities. According to Bernstein, dexterity is the most advanced sensorimotor ability (he termed it "tsarina of motor abilities"). He defines it as follows:

Dexterity is the ability to handle any situation, or solving any movement task:
1. properly (i.e. correctly and precisely),
2. quickly (i.e. without unnecessary delay),
3. rationally (i.e. intentionally and economically),
4. cleverly (i.e. efficiently and ingeniously).

It was thus the term "dexterity" that appeared in the title of his book.

Bernstein's model of movement construction in humans

In his analysis of evolution of living beings, Bernstein noticed the cause–effect dependences and gradual development of four factors determining the motor efficiency and efficacy, namely:

1. Ability to perceive stimuli from the environment and to response to them (sensibility and excitability),
2. Ability to perceive new motor tasks to be solved,
3. Occurrence of new executory organs or development of the already existing ones, as well as appearance of new parts of the central nervous system, enabling shaping new sensorimotor abilities,
4. Shaping varied sensorimotor abilities, which enable construction of new skills and capabilities, thus solving more and more complex motor tasks [7].

Accordingly, Bernstein built a model consisting of five levels, each corresponding to some particular part of the central nervous system and a specific class of motor activities. Level A corresponds to muscle tonus (*formatio reticularis* in the central nervous system, CNS), level B to muscle synergies (*globus pallidum* in the CNS), level C to movements in space (*corpus striatum* and *cortex* in the CNS), level D to complex sensorimotor performances (*cortex* in the CNS), and level E to symbolic representations of movements (*cortex* in the CNS). It could be said that level A constitutes the basis for each sensorimotor activity (like electricity for a computer or buoyancy force for a yacht), level B – the basis of coordination, level C – fully developed coordination, level D – the "motor reason", and level E – the "motor soul" of a human. Originally, it was invented as a hierarchical system, i.e. the highest level of a given movement construction "commands" the lower ones to perform their partial task automatically, without engaging attention of the performer. Hence the lower levels play the part of "background" to the highest, "commanding" level [3]. Moreover, the existence of higher levels extends the capability of lower ones, e.g. level B is not trainable in fish, but the same level B in humans, who also possess levels C, D and E, is trainable.

However, a thorough analysis of such a model poses the question: what mechanism could induce or drive the evolution? In other words, if the information flows only up–down, then what makes the higher levels to develop? Hence, there has to exist some mechanism bringing information also "upwards" (feedback). It seems that in the course of evolution only the "up-flow" of information (or requirements) at first created the perception capabilities, and then the executory capabilities, corresponding to a given formed level [7].

Bernstein's theory and contemporary motor control theories

Bernstein's conception makes a convenient basis for classification of motor control theories. They have to be clearly distinguished from motor learning theories, because the former describe the process of executing already existing motor behaviour patterns, while the latter – an essentially different process of acquiring, processing and automating such patterns.

For description of sensorimotor activities engaging levels A, B and C, James J. Gibson's theory (ecological description, emergent theory) [8] or Anatol G. Feldman's Equilibrium Point Hypothesis would be suitable [9]. However, it is only a control theory and does not include problems of activation and planning a movement, all the more a compound sensorimotor performance. Nevertheless, it is a valuable attempt at describing both symbolic projection and sensory execution of a performance with a common "language".

On levels D and E one should locate the "cybernetic" sensorimotor control theories, e.g. N.A. Bernstein's [10], Levan W. Chkhaidze's [11], and Jack A. Adams' regulation theory [12], or scheme theory developed by Richard A. Schmidt [13]. Hence, controversies between "centralists" and "peripherialists" [14], adherents of motor approach and action approach [15], or followers of prescriptive and emergent theories [16], seem unjustified. Main differences between the two different approaches to motor control have been described by Bruce Abernethy and William A. Sparrow [15] (Tab. 1).

Some more recent continuation of the old (though not resolved) contention between the "centralists" and the "peripherialists" is a dispute between adherents of programme and parametric control. The former, including e.g. forward and inverse models, belongs to static theories comparing motor control in humans to that of machines. When the arm in a machine has to end its bending at an angle of 48º13'28", then it will stop at this angle regardless of external forces. On the other hand, in parametric control there is some equilibrium between the bending angle and the acting force (or, more strictly, torque) and the eventual angle of bending results from equilibrium between the activation threshold of a muscle – being some kind of continuously, dynamically movable attractor, established in the central nervous

Table 1. Juxtaposition of the main features of "movement systems" and "action systems" approaches according to Abernethy and Sparrow [15].

Dimension of contrast	"Movement systems" approach	"Action systems" approach
Alternative label	Information-processing approach Prescriptive approach Computational approach Representational approach	Dynamical approach Emergent approach Direct approach
Philosophical origins	Belief in the man machine metaphor Implicit support of the actor–environment dualism	Belief in ecological realism Explicit support of actor environment synergy
Origin of theoretical explanation and model	Computer science and engineering	Modem physics and theoretical/comparative biology
Direction of explanatory logic	Improved explanatory power by adding sophistication and intelligence to the computational model	Improved explanatory power by seeking more fundamental processes
Nearest psychology sub-discipline	Cognitive psychology	Ecological psychology
Movement organization and control mode	Top-down, hierarchical control acting via prescription	Bottom-up hierarchical control acting through coordinative structures
Solution to the control of multiple degrees of freedom	Generalized motor programs structured and stored centrally	Coordinative structures which self assemble the dynamical properties of the motor system
Relationship of control mode to kinematics	A priori planning resulting in desired kinematics. Organization and assembly prescribed from overriding plan	Kinematics as an a posteriori consequence of the self organization and self assembly of muscle collectives.
Central representation of desired movement	Present	Absent
Translation mechanism	Essential to convert abstract plan to "language" of muscle	Not necessary; All control is in common environmental units
Role of muscle	Subserviently carries out control commands specified centrally	Determines movement form and phase interactions through dynamics
Temporal organization of movement	Temporal features of kinematics metered out through an intrinsic time keeping device	Temporal features of kinematics arise as an emergent property through preservation of invariant phase angular relationships between effectors
Relationship to perception	Independent serial processes with perception preceding action (separate stages as revealed by Sternberg's addictive factors method)	Perception and action as tightly coupled processes, functionally and evolutionally inseparable perception in units of action and vice versa
Perceptual model supported	Computational model (e.g. Marr, 1982)	Direct perception model of Gibson (1979)
Explanation of learning	Improved information processing strategies (and, with development, increased processing capacities)	Increased attunement to essential invariants and control over context-conditioned variability
Role of memory in learning	Fundamental to improve strategy formation and long term skill acquisition	Minimal role in learning. Many deny memory processes per se because of necessity to invoke representation
Type of experimental paradigm advocated	Laboratory work on contrived movements historically favoured but naturalistic work ultimately desirable	Ecological validity essential. Study of natural actions prescribed
Units of measurement	Information measured mathematically with respect to stimulus/task uncertainty and difficulty	Essential information described in units scaled to the actor

system – and external load. In other words, in programme control the most important factor is the anticipated bending angle, while in parametric control – the state of equilibrium between muscle force and external load. Usually it is dynamical equilibrium, i.e. taking into account inertia of moving objects, including the body parts.

Some experts argue that the difference between programme and parametric approach is "fundamental". However, when adopting some elements of fuzzy logic [17] to the computational programme approach, it will provide the necessary flexibility to the whole system, i.e. will enable performing the same activity each time in a slightly different manner (Bernstein's "repetitions without repetitions"). Also the probabilistic approach is very promising, being in its core a computational one [18]. Thus the difference between the programme and parametric approaches seems to be not so "fundamental" as it might appear at first glance.

Each class of motor performance corresponds to a particular motor control level with its own control mechanism. In other words, in contemporary motor science a single, universal model of human sensorimotor behaviour does not exist, at least in the group of theories including static patterns of information circulation, as all the theories mentioned above. The other group of models consists of those with dynamic information circulation patterns (clearly depending on time), e.g. the theories by Michael I. Jordan and David E. Rumelhart [19], Daniel M. Wolpert and Mitsuo Kawato [20] or – to some extent – by Ernst J. Hossner and Stefan Künzell [16], the latter including some elements of fuzzy logic.

What seems to be evident is the fact that on the lower levels (A, B and C) mainly a sensory code of information exchange is used**, i.e. extrinsic or intrinsic stimuli transformed in receptors into a series of neural impulses and perceived at the level of the first signal system according to Pavlov, without identifying them at the level of symbolic projections (abstract verbal thinking).** As far as level C is concerned, Bernstein writes about "sensory synthesis", i.e. complex of joined sensory stimuli, processed in the information circle as a single unit. The sensory synthesis can be regarded as a prototype of symbolic projection of reality (generalized word). However, on two higher levels (D and E) mainly the symbolic (verbal) code is used, **i.e. extrinsic or intrinsic stimuli perceived at the level of second signal system according to Pavlov, where to any stimulus a symbolic (verbal) meaning is ascribed.** It enables a human to use much more "concentrated" information, the processing of which can be much faster. However, such concentrated information contains inevitably some ambiguity. Nevertheless, just the two basic abilities, namely:

– the ability to use symbols – in human language joining words with their **generalized** meanings[1] [21] in information processing, and
– the ability to perceive the time as a universal factor ordering the succession of events,

seem to be the main bases of a unique, human power: capability of abstract thinking. The fact that in human motor performance the sensory and symbolic codes are used, both in motor control and motor learning, makes it necessary to establish some "translating" mechanism [22–25], because, regardless of the grade of abstractness during creation or processing the motor patterns on levels D and E, its execution is performed on level C (or some lower one) while muscles "understand" only simple, purely sensory signals – the motor commands.

Bernstein's theory and contemporary motor learning theories

Considering the fact that a human makes use of two different codes in his sensorimotor behaviour, it is possible to construct the model of **sensorimotor learning** consisting of two information circles, resembling the figure "8" (Fig. 1); it can be then termed the "eight-model" [26]. It has to be noticed that the model presented is in its form and function very similar to that proposed by Arturo Hotz [27].

The lower, sensory circle of the "eight" corresponds to shaping the sensorimotor behaviour patterns only on the stimulus–response principle, i.e. on a purely behavioural basis. Here we can speak about simple training or even primitive reflexes formation, like drilling Ivan P. Pavlov's dogs. It may be termed "zero-model" of sensorimotor learning, using only the sensory information circulation. However, the higher symbolic circle of information of the "eight" is a cognitive one.

Accordingly, acquirement of sensorimotor behaviour patterns on the "sensory circle basis" and execution of sensorimotor patterns both on the sensory and sym-

[1] "Contrivances" of apes, manifesting themselves in producing and using tools, as well as adopting "diverted traffic" in task solving – all these make, no doubt, some primitive phase of thinking development; this is, however, still the pre-language phase [21].

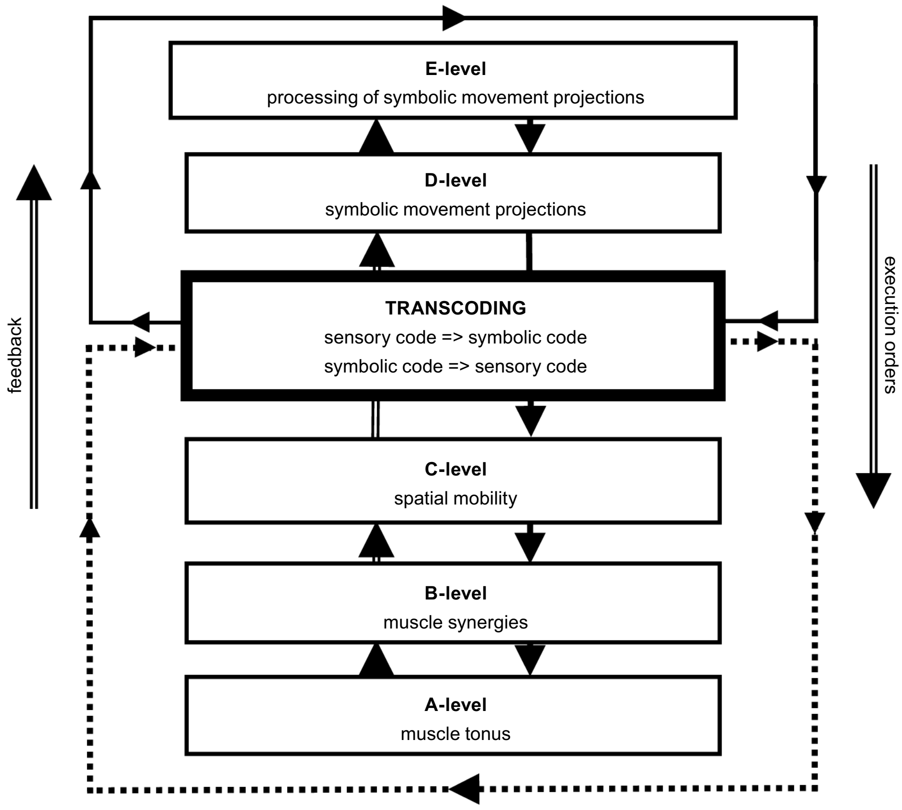

Figure 1. The learning scheme of sensorimotor skills showing the transcoding block. The lower sensory circle (levels A, B, C) makes the "zero-model", while both circles (sensory A, B, C and symbolic D, E) form the "eight-model" of sensorimotor learning [26].

bolic circle basis can be analyzed behaviourally. However, creation or processing of sensorimotor behaviour patterns on the "symbolic circle basis" has to rely upon cognitive [28] or even constructivist [29] support. In other words, we can divide all sensorimotor performances into three categories: inborn, learned and worked-out [30]. All of them – if acquired, processed and automated – can be controlled in the region of sensory (behavioural) circle of the "eight model", but creation and processing (learning) of a worked-out performance can be made only in the symbolic (verbal; cognitive or constructivist) one.

The proposed model is compatible with the general systems theory. One of the rules of the theory assumes autonomy of each system layer (which can be identified with Bernstein's motor control level), i.e. some freedom in choosing an action with minimal interference of the higher layers [31]; it remains in accordance with Bernstein's theory. Moreover, the associations between particular "layers" of each system include the flow of information "down–up" where the reduction of information occurs (it becomes more general), and "up–down" where information becomes more detailed (concrete, unambiguous) [31, 32]. It assumes the necessity of transcoding during transition from one system layer to another. In this paper, for the sake of simplicity, only the transcoding between the "sensory" levels of Bernstein's model and the "symbolic" ones is discussed. Here the Equilibrium Point Hypothesis seems to afford a good "coupling" between sensory and symbolic levels, enabling communication of both circles of the "eight-model" in some common "language".

The mathematical approach to explanation of human motor behaviour could be promising, indeed, but it has to be remembered that logic, being the fundamentals of the systems theory or cybernetics, is neither the only nor a wholly reliable (or universal) tool for examination of reality. It did not even help to bring order into mathematics itself, although such an attempt was made by Bertrand A. Russell and Alfred N. Whitehead [33, 34] already in early decades of the twentieth century. Later this impossibility was mathematically proved by Kurt Gödel [35].

According to the "eight-model", a behavioural description as presented e.g. by Schmidt [14], can explain learning only with the aid of stimulus–response level principle, i.e. conditional reflexes formation. In the behavioural context one can speak not about **sensorimotor skill**, actively acquired by a human, but about **conditional reflex**, including passive "blind obedience". Hence, the mere title of the book under consideration (*Motor Control and Learning. A* ***Behavioral*** *Emphasis*) introduces some confusion. Real learning has to use cognitive mechanisms, hence it goes out far beyond a purely behavioural paradigm. Here a reflection comes to mind that the research paradigms, being to some extent "rails for thoughts", are the highest achievements of crystallized (expert's) intelligence, while fluid (discoverer's) intelligence rejects all of them. However, as far as the famous Schmidt's schema is concerned, it is worth quoting an excerpt from Hossner and Künzell's work [16]:

> Schmidt's schema theory (1975) is a classical model of this way of reasoning (programme learning – W.P.), but it is necessary to mention some important limitation. The scheme can be regarded as a learning theory only as far as the already mastered schemes, essential for the movement execution, are analyzed. **However, the schema theory does not mention the process of acquiring a generalized motor programme**.
> (Die Schematheorie von Schmidt (1975) stellt einen Klassiker dieser Denkrichtung dar, wenn auch einschränkend anzumerken ist, dass es sich bei dieser Theorie nur insofern um eine Programmlerntheorie handelt, als dass die zu erwerbenden motorischen Schemata als für die Programmrealisierung unverzichtbare Instanzen angesehen werden, **der Erwerb der Motorikprogramme selbst jedoch nicht thematisiert wird**).

The analysis of "*already mastered schemes, essential for the movement execution*", is in fact the process of motor control (directing the movements), but not motor learning (acquiring new motor skills). The sensorimotor skills or even simple conditional reflexes are useful or even necessary, but they have to work somewhere in the background, as automated "slave" components of complex sensorimotor performances, while such human performances need some conscious, voluntary control, engaging abstract thinking and going beyond a purely behavioural research paradigm into the cognitive region. Adherents to the behavioural way of reasoning [36] argue that behaviour is the only phenomenon, which can be observed and analyzed by a researcher. This is true on the stimulus–response level, when we discuss sensorimotor reflexes or simple skills or habits, but this model shows some serious shortcomings when more complex processes, including abstract thinking, are concerned. To effectively cope with this behaviourists invented a "black box". Problems insolvable within the frames of behavioural paradigm have been "packed" into a certain "black box" without further consideration. Such a "black box" has been tightly closed and included into the system scheme as an element which does not need any further explanation. Hence, the behavioural approach seems not to be the appropriate theoretical basis for explaining the structure of a complex sensorimotor skill or performance, calling for using some abstract thinking, but especially for description of the process of their acquisition. To cut the long story short, behaviourism is by no means a primitive theory or philosophical approach – after all, its greatest achievement is cybernetics [32, 37] – but if mathematicians had thought about mathematics using the same philosophical approach, then their highest attainment would have been the multiplication table.

Discussion

Assuming the "eight-model" being true, one can attempt to construct a hypothetical model of information circulation during execution of a sensorimotor skill and general memory system (Fig. 2).

At first it has to be noticed that the popular memory system, proposed by Richard C. Atkinson and Richard M. Shiffrin in 1968 – consisting of a short-term sensory store, short-term memory and long-term memory [see 38] – discriminated individual memory components according to the time of retention. Then the other component, namely working memory [39], was added, but – as can be deduced from its name – it was the function of WM, that enabled its identification. Thus three components were chosen according to one criterion (time of retention), while the fourth – according to another one (function). It is practically impossible to build a coherent model of components selected according to different criteria. Hence it is necessary to emphasize the functions of particular elements of the human memory system. First of all, however, it is necessary to divide the entire system into two floors: the higher – symbolic and the lower – sensory.

The trainability on both the sensory and symbolic levels depends on long-term memory, thus the LTM has to be divided into two sub-components: sensory LTM and symbolic LTM. Animals use only the sensory code

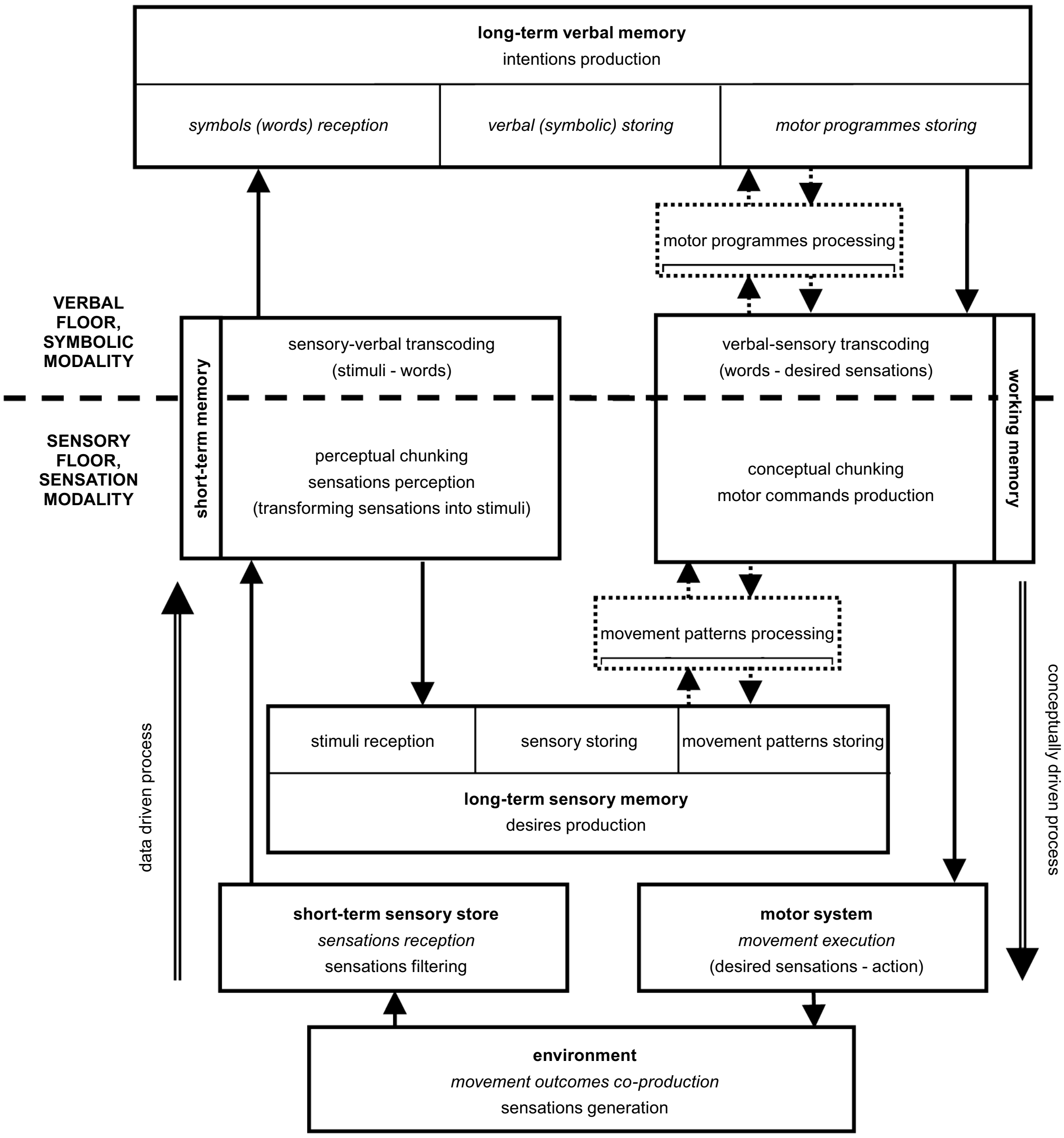

Figure 2. Circulation of information during execution and learning of human sensorimotor skills. Dotted arrows and blocks represent the learning processes, while solid lines – the control ones.

of information (levels A, B and C according to Bernstein's theory) and sensory LTM, while human beings use also the symbolic code (levels D and E) and symbolic LTM.

Next, it is necessary to ascribe particular functions to individual parts of the system. Thus, the short-term sensory store (STSS) has to play the part of a filter for sensations from the environment. The sensations passed through STSS go to STM, where they are received, identified and transformed into stimuli, evoking some response. The STM acts also as a switch: if the stimulus needs to response on the sensory floor only, then it passes to sensory LTM. Otherwise it is transcoded into a symbolic form and passes to symbolic LTM.

Working memory receives either a movement pattern from the sensory LTM, or a motor programme from the symbolic LTM. In the latter case it has to be transcoded into a sensory form, because the motor system "understands" only purely sensory motor commands. Then the WM, while in "control mode", activates the motor system. In the "learning mode" WM cooperates either with sensory LTM processing movement patterns, or with symbolic LTM processing motor programmes or even generalized motor programmes.

It is worth noticing that the model includes two transcoding blocks: sensory-verbal and verbal-sensory. As already stated, in the case of synthetic information carriers, symbols or words, we have to do with some trade-off ambiguity – information capacity (the more capacious, the less precise is the symbol). Hence, a highly synthetic symbol has to be inevitably more or less ambiguous. This is – at least partly – the reason for which voluntary skills, while performed, have some desirable flexibility. In such a scheme clearly separated is also the part played by short term [28] or working memory [39]. In both these memory blocks the transcoding process occurs, however in the STM one has to do with time abundance (multiple rehearsal), while in the WM – with time deficit. It makes a dramatic, qualitative difference between both transcoding processes, resembling verbal translating and interpreting, respectively. There are also differences between perceptual and conceptual chunking [40]. The process of chunking seems necessary for preparation of the information (either sensory or verbal) to be transcoded [22].

Symbolic-sensory transcoding during execution of sensorimotor performance by a human to some extent resembles a simultaneous interpretation [41]. In both processes reception of information and its processing have to run nearly instantaneously; hence, problems of time deficit and impossibility of correction appear. However, there is also some substantial difference between the processes. From the viewpoint of both the systems theory [31] and psycholinguistics [21], with sensory-symbolic transcoding (which could be compared to intersemiotic linguistic translation [42]), the information becomes more general, while with symbolic-sensory transcoding – more detailed. However, in the course of linguistic conversion both the original and translated texts are characterized by the same level of generality (or "detaility").

The "long-term memory" block in the scheme presented in Fig. 2 remains in accordance with the LTM model proposed by Endel Tulving, consisting of three components: semantic memory store, procedural memory and episodic memory [43]. The sub-block "*verbal (symbolic) storing*" in Fig. 2 can be regarded as a part of the semantic memory store, the sub-block "*motor programmes storing*" – as a part of the procedural memory, while the episodic memory may contribute to production of intentions.

The "working memory" and "motor system" blocks correspond, to some extent, to the forward (Fig. 3) and inverse models (Fig. 4), respectively [19].

However, they cannot be identified with them, mainly because the presented scheme is a static image, while both the forward and inverse models are dynamic descriptions (clearly depending on time). It is also worth mentioning that the forward model produces a **predicted** sensation, while the inverse one is based on the **desired** sensation; hence, including it into a simple graphical scheme seems to be hardly possible. Here we come across some inconsistency in terminology, slightly impeding understanding of Jordan and Rumelhart's description. Namely, a human can perceive "state x" by only his senses. Therefore, it exists in his mind only as a current sensation or some conglomerate (synthesis) of sensations. Accordingly, in Jordan and Rumelhart's

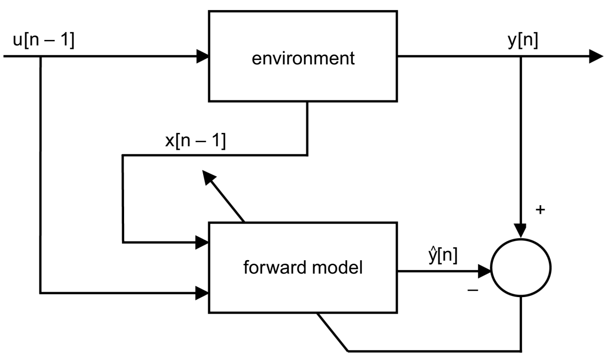

Figure 3. Forward model (predictor): u[n–1] – former action; y[n] – actual sensation; x[n–1] – former state of environment; ŷ[n] – predicted sensations. The forward model compares predicted sensations ŷ[n] to actual sensations y[n] and uses the resulting prediction error to adjust the parameters of the model [19]

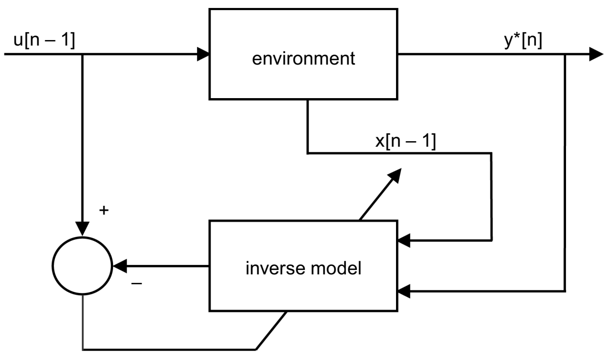

Figure 4. Inverse model (controller). The symbols mean: u[n – 1] – action; y*[n] – desired sensation; x[n – 1] – current state of environment. The inverse model produces an action u[n – 1] as a function of the current state x[n – 1] and the desired sensations y*[n] [19]

model we deal in fact with only two kinds of events, namely actions and sensations (predicted, desired and current ones, the latter denoted as certain "state x"), as was described by Hossner and Künzell [16].

The common denominator of the model presented in Fig. 2 and 3, as well as both the forward and inverse models by Jordan and Rumelhart, constitutes the central process: **transcoding**, verbal-sensory and sensations-actions (or inversely). The notions "*data driven process*" and "*conceptually driven process*", used in Fig. 2, have been introduced by Peter H. Lindsay and Donald A. Norman, and are commonly used in psycholinguistics [23]. However, humans reveal close connections between movement and language production (and its verbal expression). Language, being in human phylogeny a much younger phenomenon than motor activity, in the course of its development used the nervous connections which had already existed and were employed for motor control [44]. So, applying these terms for description of human motor behaviour seems fully justifiable.

The proposed model, if assumed to be true, calls for some change in the general conception of working memory. According to John R. Anderson [28], the WM can freely use data from all other memory components. However, according to the scheme presented in Fig. 2, an important element of WM is the verbal-sensory transcoding mechanism. Hence, it seems to be uneconomical, i.e. against the general "philosophy" of nature, to include also sensory-verbal mechanism into this memory component, because it exists already in the STM. Hence, it seems logical that the WM cannot receive the sensory data directly from the STSS, but only stimuli from the STM, perceived and then transcoded into verbal form.

Conclusions

Bernstein's theory seems to be a very useful tool for bringing order and logical terminology into contemporary knowledge about human sensorimotor learning and control (Tab. 2).

It is worth noticing that in the column "motor learning", line "E – level", there is a cell termed "Imaginary motor grammar". The close relation of movement and language production in humans has already been mentioned [22, 23, 44]. It is not a case of a more or less complex model of motor behaviour, but some kind of meta-model, or a set of rules enabling construction of proper sensorimotor patterns of human behaviour. In its struc-

Table 2. Bernstein's theory and contemporary theories of human sensorimotor activity; the Equilibrium Point Hypothesis (EPH) reduces the motor control process to the sphere of space, time and movement, but not internal models of motor performances.

Sensorimotor associations, main code type	Motor control level	Motor control mechanism	Motor control theory	Motor learning	Learning paradigm
Symbolic levels, complex associations symbol-activity, **verbal code**	E – motor programmes creation	No motor control mechanism	No motor control theory	Imaginary motor grammar	Cognitive and constructivist approach
	D – motor programmes execution	Generalized motor programme	Cybernetic theories (Bernstein's, Adams', Chkhaidze's, Schmidt's, etc.)	Creation of generalized motor programmes	Behavioural and cognitive approach
Transcoding sensory-verbal (up) or verbal-sensory (down); Equilibrium Point Hypothesis					
Sensory levels, stimulus–reaction associations, **sensory code**	C – spatial mobility	Central patterns generator (highly flexible)	Gibson's ecological theory	Creation of new behaviour pattern generators	Behavioural approach
	B – muscle synergies	Central patterns generator (hardly flexible)			
	A – muscle tonus	Central patterns generator (stiff, on-off state)			

ture and function such a metamodel resembles linguistic syntax or – more generally – grammar (the latter notion includes both syntax and morphology of a language). The adjective "imaginary" means that the behaviour pattern arises first in the human mind, and only later it is performed in practice, hence in such a case we deal with a conceptually driven process including a deductive way of thinking during shaping the sensorimotor behaviour patterns (worked-out performance). On the contrary, learned sensorimotor behaviour patterns are acquired from outside (there is some "external teacher"); they arise in the course of data driven process and use the inductive way of thinking.

It has to be noticed that this paper deals only with the "static" theories of motor control and learning, i.e. with descriptions including schemes or models which are not evidently dependent on time. The "dynamic" ones, assuming time dependence (i.e. probably changing the behaviour pattern during execution of a given sensorimotor performance), are e.g. like those by Jordan and Rumelhart, Wolpert and Kawato or Hossner and Künzell. The static theories are no longer suitable to explain the mechanism of human motor behaviour, thus it seems to be inevitable that scientists have to turn to dynamic theories. It is an important transformation of research paradigm which could be identified with scientific revolution as defined by Thomas S. Kuhn [45]. The following statement by Schmidt and Lee provides a useful explanation [46, p. 416].

> Schema theory has provided an alternative to Adams' closed-loop theory of motor learning. Compared to Adams' theory, it has the advantage that it accounts for more kinds of movements; it seems to account for error-detection capabilities more effectively and seems to explain the production of novel movements in open-skills situations. Some logical problems need to be solved, and it is not clear whether it can be done without discarding the entire theoretical structure.

Nevertheless, the different "static" theories, which enlighten the human motor function structure from various perspectives, form a necessary "starting point" for analyzing more sophisticated descriptions of human motor control and learning, i.e. dynamic theories. The "static" theories merely form a reliable ground and fertile soil for development of much more advanced and complex "dynamic" models. It is then necessary to bring order into the already existing "static" knowledge[2], to be able to explore it fully by building new, dynamical models of sensorimotor performances. Here the theory of systems and cybernetics can be of great value. Nevertheless, it should also be remembered that logic, being the cornerstone of the systems theory and cybernetics, is neither the only nor a fully reliable (or universal) assessment tool.

The following conclusions might be formulated:

1. There is no universal theory describing the control mechanism of **all** human sensorimotor performances.
2. There is no universal theory describing the control mechanism of a **single** human compound sensorimotor performance.
3. The era of "static" theories – the structure of which remains unchanged during the whole execution process of a sensorimotor performance in humans, as e.g. Gibson's, Adams' or Schmidt's – in motor control *is over*! These theories can retain their significance only in didactics.
4. Bernstein's model, along with ENHANCED contemporary theories, e.g. Jordan and Rumelhart's (forward and inverse models in motor control) or Wolpert and Kawato's (multiple paired inverse and forward models), but also some earlier models, e.g. Rilo Pöhlmann's or Arturo Hotz and Jürgen Weineck's, may constitute a good basis for development of a new dynamical theory (or theories) of motor control in humans, which describes human sensorimotor performances in a much better way.
5. The current motor control theories seem to be more and more inefficient, and there is not any clearly visible way of solving the problem. Hence, it is very probable that at least in motor control – and possibly in physical culture in general – we are just on the eve of scientific revolution, as described by Kuhn, i.e. a thorough change of the research paradigm.
6. Whatever the new paradigm will be, Bernstein's model seems to be an excellent tool for thorough settlement of the whole of current knowledge in motor science.

References

1. Bernstein N.A., On the construction of movements [in Russian]. Medgiz, Moskva 1947.

[2] It seems to be psychologically justified that a scholar, who discovers or invents something, strives to underline its originality, novelty, importance and distinctness. We owe some esteem to discoverers indeed, but science as a whole should be as homogenous as possible, hence ordering it consists to a great extent in "smoothing out" any distinctness or melting together different hypotheses and models into one efficient and efficacious unit.

2. Bernstein N.A., The coordination and regulation of movements. Pergamon Press, Oxford 1967.
3. Bernstein N.A., On dexterity and its development [in Russian]. Fizkultura i Sport, Moskva 1991.
4. Czajkowski Z., On strange fates of people and books and on Bernstein's posthumous victory [in Polish]. *Sport Wyczynowy*, 1992, 3–4, 103–106.
5. Fejgenberg J.M., Nikolai Bernstein – from a reflex to the model of future [in Russian]. Smysl, Moskva 2004.
6. Bernstein N.A., On dexterity and its development. In: Latash M.L, Turvey M.T. (eds.), Dexterity and its development. Lawrence Erlbaum Associates, Mahwah, New Jersey, 1996, 3–244.
7. Petryński W., Contemporary motor control models in the light of Bernstein's theory [in Polish]. *Antropomotoryka*, 2005, 15(29), 55–67.
8. Gibson J.J., The Ecological Approach to Visual Perception. Houghton Mifflin, Boston 1979.
9. Latash M.L., The Past and Present of the Equilibrium Point Hypothesis. *Journal of Human Kinetics*, 2000, 4, Suppl., 25–37.
10. Bernstein N.A., Some maturing problems of movement acts regulation [in Russian]. *Voprosy Psikhologii*, 1957, 6, 70–90.
11. Chkhaidze L.W., Voluntary movements coordination and motor habits formation in the light of general control rules and control systems principles [in Polish]. *Wychowanie Fizyczne i Sport*, 1962, 2, 155–161.
12. Adams J.A., A closed-loop theory of motor learning. *Journal of Motor Behavior*, 1971, 3, 111–150.
13. Schmidt R.A., Wrisberg C.A., Motor Learning and Performance. Human Kinetics, Champaign 2004.
14. Schmidt R.A., Motor Control and Learning. A Behavioral Emphasis. Human Kinetics, Champaign 1988.
15. Abernethy B., Sparrow W.A., The Rise and Fall of Dominant Paradigms in Motor Behaviour Research. In: Summers J.J. (ed.), Approaches to the Study of Motor Control and Learning. Elsevier Science Publishers, North Holland 1992, 3–45.
16. Hossner E.J., Künzell S., Motor learning [in German]. In: Mechling H., Munzert J. (eds.), Handbuch Bewegungswissenschaft – Bewegungslehre. Verlag Hofmann, Schorndorf 2003.
17. Zadeh L.A., Fuzzy sets. *Information and Control*, 1965, 8, 338–353.
18. Feigenberg I.M., Memory of the past for probabilistic prognosis of the future [in Polish]. *Antropomotoryka*, 2006, 34, 17–32.
19. Jordan M.I., Rumelhart D.E., Forward models: Supervised learning with a distal teacher. *Cognitive Science*, 1992, 16, 307–354.
20. Wolpert D.M., Kawato M., Multiple paired forward and inverse models for motor control. *Neural Networks*, 1998, 11, 1317–1329.
21. Wygocki L.S., Thinking and language [in Polish]. In: Wybrane prace psychologiczne. PWN, Warszawa 1971, 159–488.
22. Petryński W., Translation issues in human movements control [in Polish]. X Międzynarodowa Konferencja Translatoryczna, Instytut Tłumaczy Tekstów i Konferencji, Wydział Nauk Humanistycznych, Akademia Polonijna, Częstochowa 2005.
23. Kurcz I., Memory, learning, language [in Polish]. PWN, Warszawa 1995.
24. Clark J.M., Paivio A., Dual coding theory and education. *Educational Psychology Review*, 1991, 3(3), 149–170.
25. Olshausen B., Field D.J., Sparse coding of sensory inputs. *Current Opinions in Neurobiology*, 2004, 14, 481–487.
26. Petryński W., Motor control and learning according to Bernstein's theory, conference Sport Kinetics 2005, Scientific Fundaments of Human Movement and Sport Practice, International Association of Sport Kinetics, Faculty of Exercise and Sport Sciences University of Bologna and University of Bologna Sport Center. September 2005, Rimini Italy.
27. Hotz A., Qualitative motor learning [in German]. Schweiz. Verband für Sport in der Schule, Bern 1997.
28. Anderson J.R., Learning and Memory. An Integrated Approach [in Polish]. WSiP, Warszawa 1998.
29. Bruner J., Going Beyond the Information Given. Norton, New York 1973.
30. Petryński W., Scholar's Adventures in the Movementland [in Polish]. *Sport Wyczynowy*, 2004, 7–8, 136–141.
31. Morawski J., Dominants in system approach [in Polish]. In: Morawski J. (ed.), Wybrane problemy metodologii badań na potrzeby sportu. AWF, Warszawa 2000, 104–127.
32. Dąbrowski W.R., System-cybernetic approach to teaching specific skills in qualified sports exemplified by sailing [in Polish]. AWF, Kraków 2002.
33. Barrow J.D., Pi in the sky. Counting, thinking and being [in Polish]. Prószyński i S-ka, Warszawa 1992.
34. Russell B., Wisdom of the West [in Polish]. Penta, Warszawa 1994.
35. Casti J.L., DePauli W., Gödel. Life and Logic [in Polish]. CiS, Warszawa 2003.
36. Tolman E.C., Purposive Behavior in Animals and Men [in Polish]. PWN, Warszawa 1995.
37. Kozioł R., Dąbrowski W.R., Cybernetics for students of Sport Academy [in Polish]. AWF, Kraków 2002.
38. Baddeley A.D., The Psychology of Memory. In: Baddeley A.D., Kopelman M.D., Wilson B.A. (eds.), The Essential Handbook of Memory Disorders for Clinicians. John Wiley & Sons Ltd., New York 2004, 1–13.
39. Smith E.E, Jonides J., Neuroimaging analyses of human working memory. *Proceedings of the National Academy of Sciences of the United States of America*, 1998, 95, 12061–12068.
40. Postal V., Expertise in cognitive psychology: Testing the hypothesis of long-term working memory in a study of soccer players. *Perceptual and Motor Skills*, 2004, 99, 403–420.
41. Dąmbska-Prokop U., Simultaneous translation [in Polish]. In: Dąmbska-Prokop U. (ed.), Mała encyklopedia przekładoznawstwa. Educator, Częstochowa 2000, 257–258.
42. Dąmbska-Prokop U., Translation types [in Polish]. In: Dąmbska-Prokop U. (ed.), Mała encyklopedia przekładoznawstwa. Educator, Częstochowa 2000, 12–13.
43. Tulving E., How many memory systems are there? *American Psychologist*, 1985, 40(4), 385–398.
44. Allott R., The motor theory of language. In: Von Raffler-Engel W., Wind J., Jonker A., Studies in Language Origins, Vol. 2. John Benjamins Publishing Company, Amsterdam-Philadelphia 1991, 123–157.
45. Kuhn T.S., The Structure of Scientific Revolutions. University of Chicago Press, Chicago 1962.
46. Schmidt R.A., Lee T.D., Motor control and learning. A behavioral emphasis. Human Kinetics, Champaign 2005.

Paper received by the Editors: November 15, 2005.
Paper accepted for publication: October 16, 2007.

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