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THE CORRELATION BETWEEN SPORTS RESULTS IN SWIMMING AND GENERAL AND SPECIAL MUSCLE STRENGTH

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SUMMARY

Introduction. Swimming as a sport encompasses various styles and distances (from 50 up to 1,500 meters). The correlation between sports results and general/special muscle strength seems unquestionable. **Aim.** The purpose of this paper is to answer the question related to maintaining the proportion between muscle strength development (which depends mainly on land-based trainings) and endurance trainings in water. **Material and methods.** The study covered 14 leading swimmers from MKP Szczecin who specialized mainly in short and medium distances; they were members of the national senior and junior teams in the 2013/14 training year. The general strength tests were conducted at the beginning and at the end of the winter and summer preparatory periods. The following tests were performed: bench-pressing, pull-ups and bar dips. At the end of the main research period, a thrust test was conducted on land (on a swim bench), as well as a thrust test in the water. **Results.** All participants demonstrated progress in results between the summer season and the winter season. The range of training loads was higher in the summer due to the length of preparation (by about 100%). The individual progress was, however, very varied. **Conclusions.** The level of sports progress achieved by individual swimmers was greatly diversified. The relatively high level of general and special strength in the tested swimmers was linked to their need to display these motor skills while swimming. Subjects who showed the greatest progress in the general and special strength trials, displayed the biggest improvement in their swimming performance during the competition season. Swimmers with a fairly high level of strength, but a moderate sports level should analyze and improve their swimming technique. Subjects whose progress in general and special strength tests was the least significant, should try and achieve progress by developing other technical and coordination skills.

Keywords: swimming, strength training, special strength, general strength, swimmers, sports result

INTRODUCTION

The dynamic development of swimming observed in recent years puts this discipline at the forefront of all sports. Strong competition on the international arena requires constant control of the athlete's training status, as well as searching for new solutions in the training process, which would allow to achieve sports championship. Models of biomechanical parameters which determine sports results in swimming are being created (Seifert and Chollet 2009).

Swimming as a sports discipline includes a variety of men's and women's races, which span from 50 m to 1,500 m. As a result, there is a division of swimming distances into: short (50 and 100 m), medium (200 and 400 m) and long ones (800 and 1,500). This great variety (50 m vs 1,500 m) translates into a significantly difference in time of athlete’s physical effort during competition. Therefore, athletes practicing for various races display various levels of training intensity (Łubkowska and Troszczyński 2013).

Swimming belongs to endurance sports (Banach et al. 2015), where hybrid motor skills are preferred, i.e. strength, endurance, and speed. Achieving a high level of technical skills is not possible without a high level of various ‘tactile sensations’ manifested during motor activities. All kinds of these ‘sensations’ are associated with the manifestation of strength, spatial accuracy and temporal accuracy (Starosta 1984; Starosta 2012).

Introduction of sprint distance to the program of the Olympic Games and the World Championships set new goals for scientists and trainers. A need to develop specific sprint training programs emerged. This means that apart from endurance, strength has become particularly important (Kalczyński et al. 2005; Morouço et al. 2011; Wiażewicz 2016; Wiażewicz and Eider 2016). Shaping coordination skills is a way to use the potential of strength and endurance more effectively (Szark-Eckardt et al. 2017). Strength accuracy is one of the basic coordination skills which determine effective and economic performance of motor activities (Starosta et al., 2016). Swimming performance depends largely on muscle strength and power (Girold et al. 2007). The optimal level of strength and power is essential for effective swimming because it is related to maximizing the ability to generate propelling forces and minimizing the resistance of the aquatic environment (Newton et al. 2002; Vilas-Boas et al. 2010). Reaching higher speeds results from overcoming much higher water resistance, and consequently, the athlete is required to have adequate strength during a certain timespan. This is a special strength (Kalczyński et al. 2005), and it has a significant influence on the achieved sports results.

Dry-land strength training may increase the ability to generate propelling forces in water, especially for short distances. Additionally, the speed of movement should be taken into account, as it may improve the specificity of the training exercises (González-Badillo and Sánchez-Medina 2010). Strength exercises are also focused on the development of special strength. Research by Aspenes et al. (2009) showed a high correlation between upper limb muscles strength and swimming speed. The improvement of arm muscle strength may result in a higher level of strength during the stroke and, consequently, higher swimming speed, especially in sprint races (Strzała and Tyka 2009; Morouço et al. 2011). Upper and lower limb max. strength parameters and max. torso strength are good predictors of sprint races amongst young swimmers (Keiner et al. 2015). It should be taken into account that the effectiveness of strength training of swimmers depends on many factors – their genetic predispositions (Grenda et al. 2015), training methodology and off-training factors: post-workout recovery and nutrition (Łubkowska et al. 2014).

Strength training programs are a popular practice among swimmers (Aspenes et al. 2009; Garrido et al. 2010). Swimming strength training is dominated by isokinetic ergometers. Research on this type of exercise indicates an increase in power, specific to the speed of movement during trainings (Płatonow 1997). This means that the developed strength may increase the pulling power only at those speeds at which it was trained. It results in a need to determine the current capabilities of each athlete, so that proper training loads can be planned.

Some researchers question strength training because many trainers believe it may increase muscle mass (hypertrophy) or decrease flexibility, which may adversely affect athletes' movement in the water and increase resistance (Newton et al. 2002). Research conducted by Garrido et al. (2010) showed that it cannot be unequivocally stated that strength training allowed for increased swimming performance, although there was a tendency to improve sprint performance through strength training.

In summary, strength is considered to be one of the most important factors affecting swimming performance, however the results research so far have been ambiguous and the correlations varied. An interesting subject of further research are dependencies between the swimmers' sports level and their general and special strength.

The purpose of this study was to determine the impact of swimming training on general and special strength, as well as to indicate the relationship between the sports level and strength of the subjected swimmers. An additional purpose of the study was to analyze the proportions of muscle strength development (which depends mainly on land-based trainings) and endurance trainings in water.

MATERIAL AND RESEARCH METHODS

14 leading athletes from the MKP Szczecin sports club took part in the research. Subjects had trained from the first grade in a sports school (average training period of 12.36 ± 1.34 years). They were all medalists or finalists of the Polish Championship and members of the National Team of Juniors and Seniors in the training year 2013-2014. They trained in the same group by implementing a similar training program; they specialized mainly in medium and short distances. The average age at the time of the first tests was 18.36 ± 1.34 years. Detailed characteristics of the subjects – mean values (M), standard deviation (SD) and the scope of the analyzed variables (minimum-maximum) is presented in Table 1.

Table 1. Characteristics of subjects (n=14, test I)

	M	SD	Min.	Max.
Body height (cm)	183.64	3.23	177.0	188.0
Body mass (kg)	76.07	5.70	65.8	82.4
BMI ($kg{\cdot}m^{-2}$)	22.50	1.33	19.9	24.3
Age (years)	18.36	1.34	16.0	20.0
Training experience (years)	12.40	1.34	10.0	14.0

n = sample size, M = mean, SD = standard deviation, Min. = minimum, Max. = maximum, BMI = body mass index.

Source: Authors' own work based on own studies.

The subjects took part in 2 measurement sessions organized at the beginning of the macrocycle (September) and at the end of the transitional period (March). Th athletes trained twice a day, six times a week.

The assessment of their morphological results was based on the measurement of body height [cm], body mass [kg], body mass index BMI and fat content [%], using Tanita body composition analyzer, model BC-420 MA (Japan).

The value of general strength was determined on the basis of the test: strength of upper limbs – pull-ups [number of pull-ups] and bar dips [number of dips] carried out twice – at the beginning and end of the winter and summer preparation period.

The value of thrust on land [N] was determined by measuring upper limb performance on land on a swimming bench, carried out using an ergometer (Vasa SwimErg Trainer), DS2 electronic dynamometer IMADA (Japan) with an internal sensor 2000N. Measurements were made in the breast and back position, depending on the swimming style of the main race of individual athletes. The measuring system used when testing the thrust in water is shown in Figure 1.

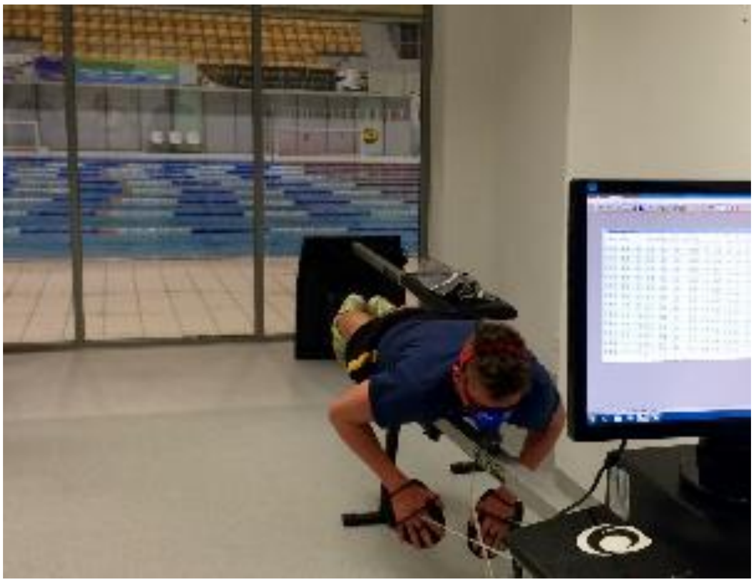


Figure 1. The measuring system used when testing the thrust on land

Source: Photo by W. Łubkowska.

The thrust force value in water was based on the measurements obtained during the strength test of upper limbs, legs and full style test performed with a DS2 IMADA electronic dynamometer (Japan) with an internal sensor 2000N. The test was carried out in the main swimming style of each athlete. The measuring system used when testing the thrust in water is shown in Figure 2.

The assessment of the sports level [in points] employed the European Ranking with so-called *Pool Swimming Scoring Tables* of the European Federation of Swimming (LEN). The results were downloaded from the website of the Polish Swimming Association (https://www.swimrankings.net).

Empirical data was analyzed statistically using SPSS 23 (IBM Chicago, IL, USA). The characteristics of the response distributions were determined (Shapiro Wilks test) and the correlation between variables and significance of differences were calculated. Statistically significant indicators had to meet the condition of $p \leq 0.05000$.

Figure 2. The measuring system used when testing the thrust in the water

Source: Authors' own work.

RESULTS AND DISCUSSION

The aim of the conducted study was the assessment of general and special strength and its changes under the influence of training loads in the macrocycle of swimmers. Strength depends largely on muscle mass, which on average makes up about one third of men's body weight, and can even reach up to 50% of body mass in individuals involved in special trainings (Bober and Hay, 1990).

Swimming 'on a leash' may help predict achievements and diagnose technical problems. The force generated during leash swimming, however, is not the same as the propelling force during free swimming (Rachel 1981; Morouço et al. 2014).

Table 2 presents the characteristics of the general strength of athletes' upper and lower limbs on land and in water (n = 14), recorded at the beginning and end of the winter and summer season preparation period: September (test I) and March (test II). The sports level of swimmers at the beginning of the macrocycle (September) and at the end of the transition period (March) is also shown.

Table 2. The characteristics of the general strength of athletes' upper and lower limbs on land and in water (n = 14), recorded in September (test I) and March (test II)

	Test	n	M	Me	∑	Min.	Max.	SD^2	SD2
Thrust force RR/land/[N]	I	14	440.4	479.5	6166.0	347.0	540.0	5767.34	75.94
	II	14	496.3	510.5	6948.0	400.0	582.0	4964.68	70.46
Thrust force NN/water/ [N]	I	14	144.5	147.5	2023.0	110.0	184.0	543.04	23.30
	II	14	153.9	151.5	2154.0	113.0	182.0	435.82	20.88
Thrust force NN/water [% to style]	I	14	62.7	63.9	877.2	52.5	78.0	56.98	7.55
	II	14	60.4	59.9	845.8	48.8	69.0	39.42	6.28
Thrust force RR/water [N]	I	14	175.9	156.0	2462.0	150.0	228.0	811.52	28.49
	II	14	194.3	200.5	2720.0	134.0	232.0	851.76	29.18
Thrust force RR/water [% to style]	I	14	76.8	73.8	1075.1	61.7	97.8	166.68	12.91
	II	14	76.2	72.0	1066.7	69.9	99.1	95.02	9.75
Thrust force NN+RR/water [N]	I	14	320.4	331.5	4485.0	265.0	378.0	1404.40	37.48
	II	14	348.1	360.5	4874.0	247.0	384.0	1962.90	44.30
Thrust force style/water [N]	I	14	231.4	237.0	3240.0	168.0	265.0	953.19	30.87
	II	14	256.1	258.0	3586.0	189.0	301.0	1280.59	35.79
Thrust force style/water [% of sum NN+RR]	I	14	72.4	75.5	1013.1	61.7	79.7	48.00	6.93
	II	14	73.8	74.4	1033.1	60.9	83.8	44.18	6.65
Sports level [points]	I	14	715.4	699.5	10015.0	513.0	844.0	8897.63	94.33
	II	14	736.2	713.0	10307.0	579.0	873.0	8703.72	93.29

RR - upper limbs, NN - lower limbs.

Source: Authors' own work.

Table 3 and diagrams 1-4 present the characteristics of the general strength of athletes' upper and lower limbs on land and in water (n = 14), recorded at the beginning and end of the winter and summer preparation period: September (test I) and March (test II).

Compared to the first measurement, an increase in the relative strength of all the tested parameters was discovered. The most significant increases were identified in the relative strength of the upper limbs (RR) measured on land and in water, as well as in the relative strength of the full style measured in water. The observed differences were statistically significant ($p < 0.05000$). The smallest increase in value was recorded for the relative strength of the lower limbs (NN) measured in water; the differences were statistically insignificant.

Table 3. The characteristics of the relative strength of athletes' upper and lower limbs on land and in water (n = 14), recorded in September (test I) and March (test II)

	Test	n	M ± SD	t test
Relative strength RR/land [N/kg]	I	14	5.81 ± 1.04	- 4.86 *
	II	14	6.44 ± 0.99	
Relative strength NN/water [N/kg]	I	14	1.90 ± 0.30	-2.09
	II	14	1.99 ± 0.28	
Relative strength RR/water [N/kg]	I	14	2.32 ± 0.41	- 2.32 *
	II	14	2.52 ± 0.38	
Relative strength style/water [N/kg]	I	14	3.04 ± 0.37	- 5.33 *
	II	14	3,32 ± 0,44	

* - differences are significant with p <0.05000

Source: Authors' own work.

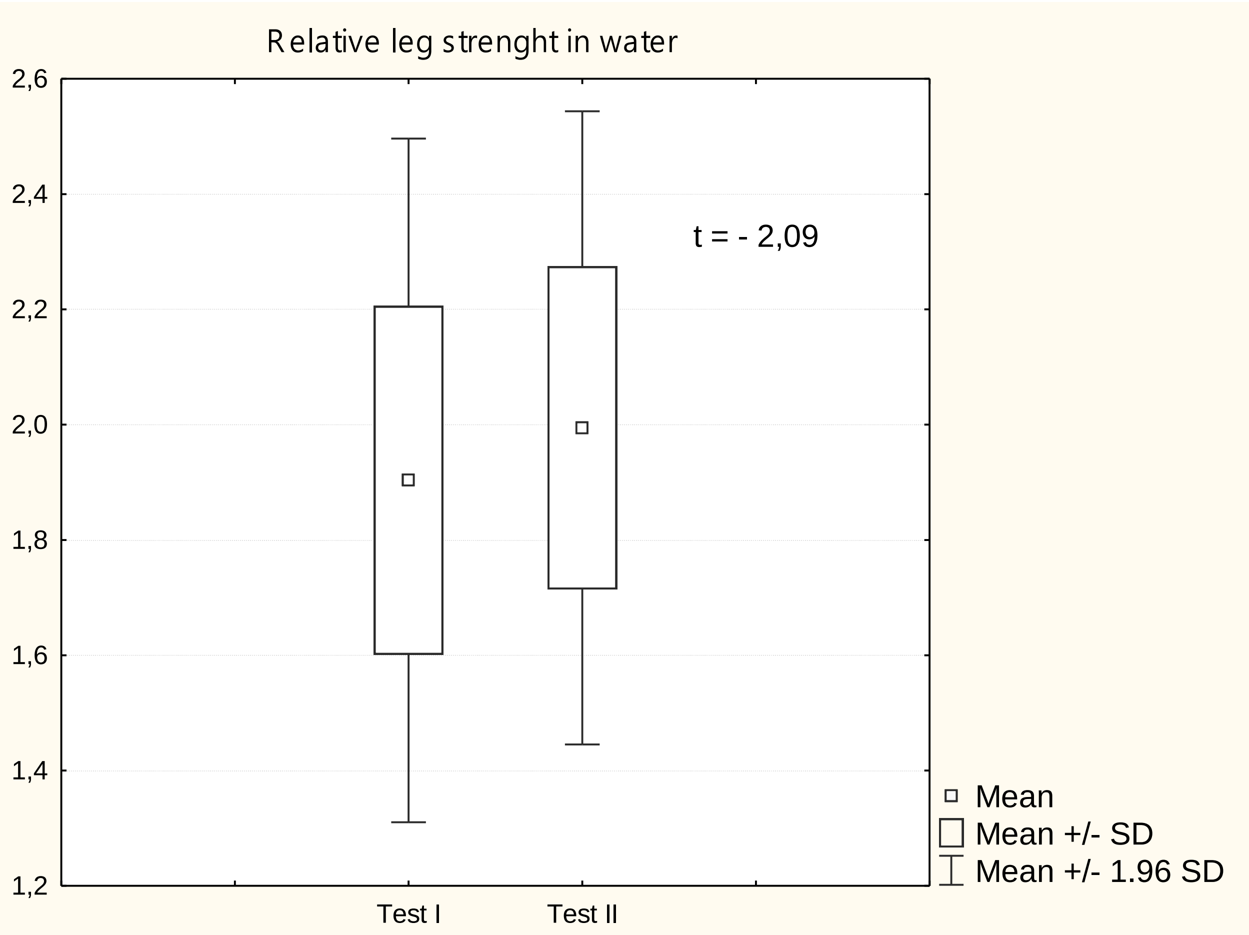
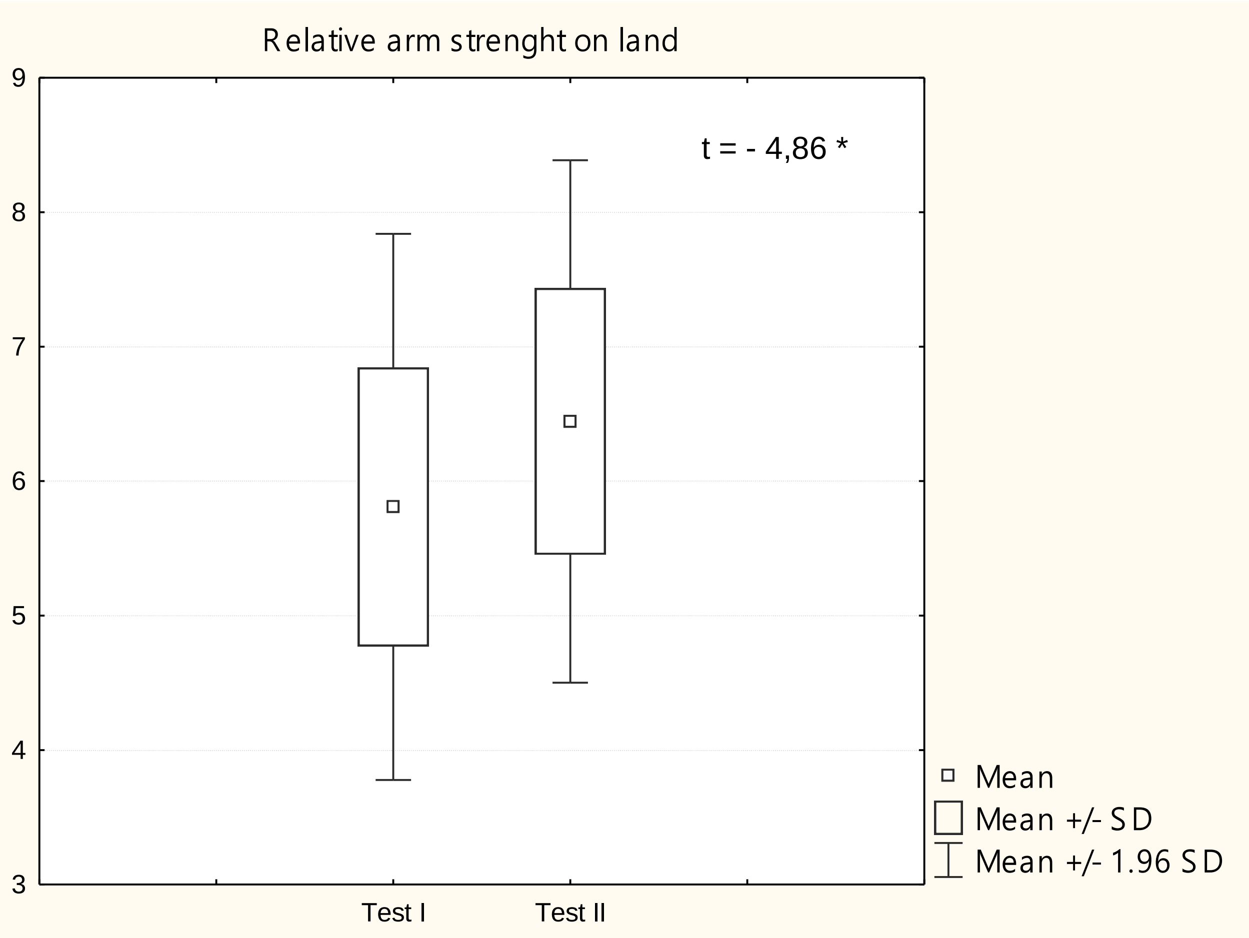


Diagram 1. Mean values (± SD) of the relative strength [N/kg] of athletes' lower limbs (n=14), recorded in water in September (Test I) and March (Test II)

Source: authors' own work.



Relative arm strenght on land
t = - 4,86 *
9
8
7
6
5
4
3
Test I
Test II
Mean
Mean +/- SD
Mean +/- 1.96 SD

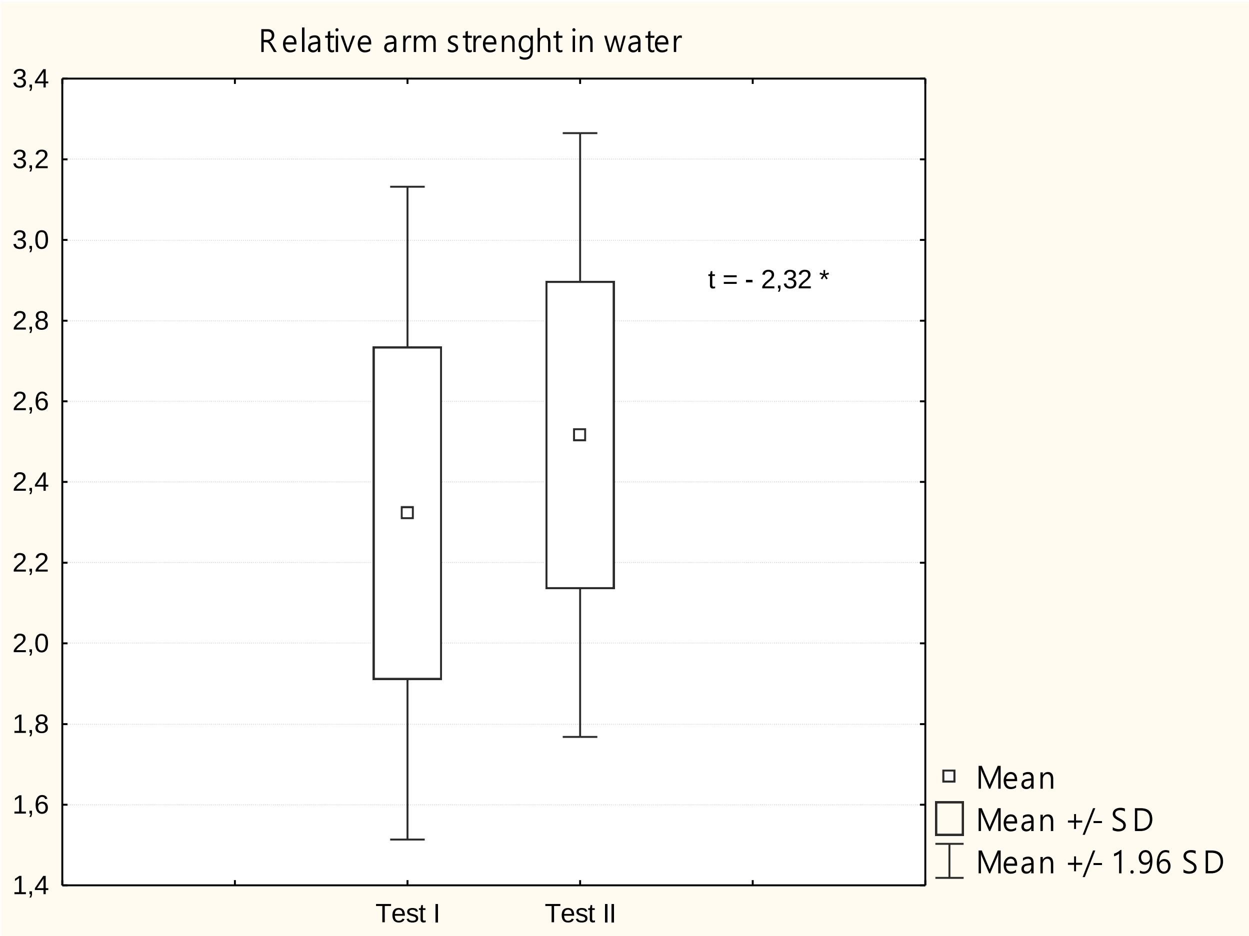


Diagram 2. Mean values (± SD) of the relative strength [N/kg] of athletes' upper limbs (n=14), recorded on land and in water in September (Test I) and March (Test II)

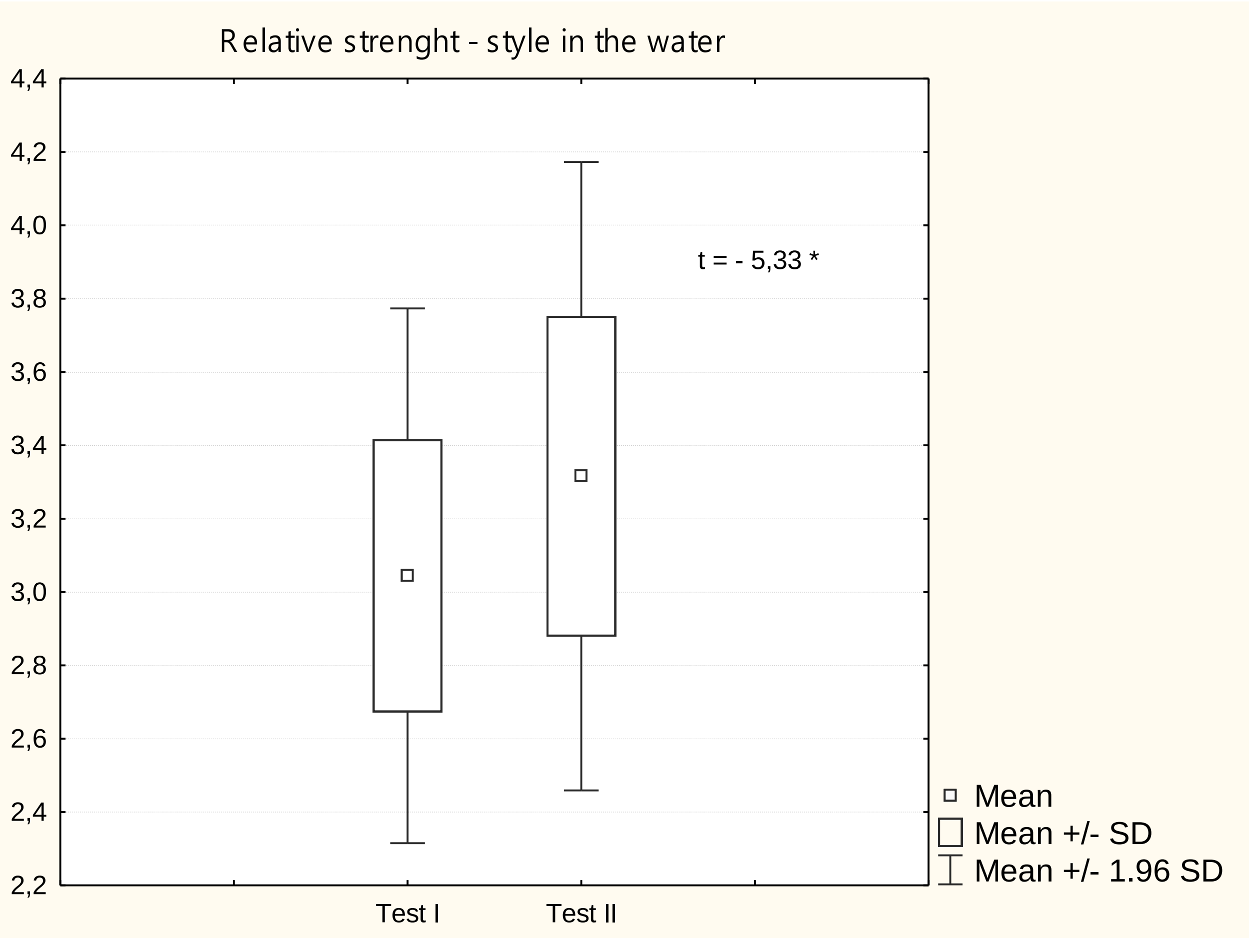
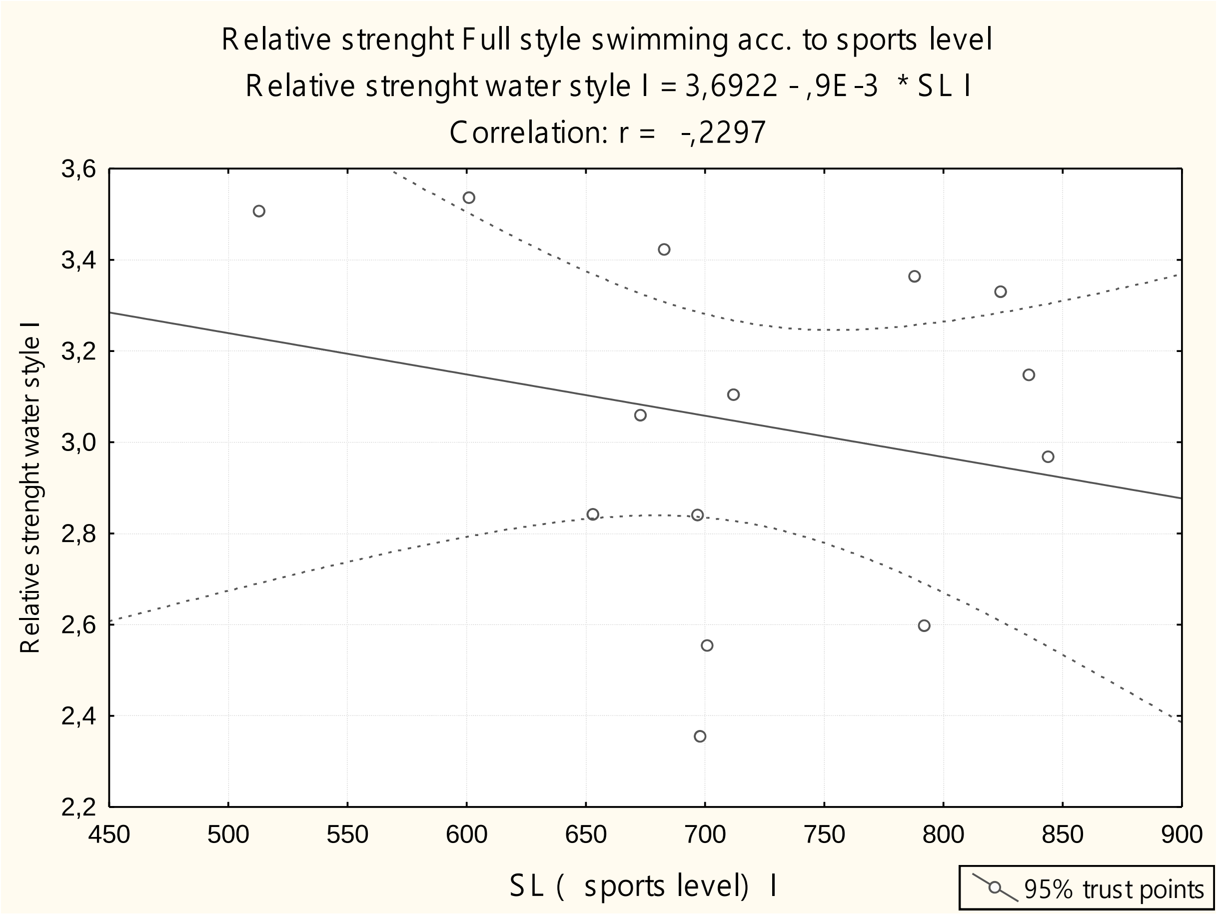


Diagram 3. Mean values (± SD) of the relative strength [N/kg] of athletes' upper and lower limbs (n=14), recorded in water in September (Test I) and March (Test II)

The obtained results (Diagrams 1-4) indicate significant changes in the strength level of the subjects during the winter and summer competition periods of the Polish Championship. All participants demonstrated progress in results between the summer season and the winter season. The range of training workloads was higher in the summer due to the length of preparation (by about 100%). The individual progress was, however, very varied. Subjects who showed the greatest progress in the trials, obtained the biggest improvement in their swimming performance during the competition season. Certain varieties between the athletes (a fairly high level of strength, but a moderate sports level) was identified mostly in individuals with poor swimming technique. Athletes whose progress in general and special strength tests were the least significant, should try and achieve progress by developing other motor and technical skills.


Relative strenght Full style swimming acc. to sports level
Relative strenght water style I = 3,6922 - ,9E-3 * SL I
Correlation: r = -,2297
Relative strenght water style I
3,6
3,4
3,2
3,0
2,8
2,6
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450
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550
600
650
700
750
800
850
900
SL (sports level) I
95% trust points

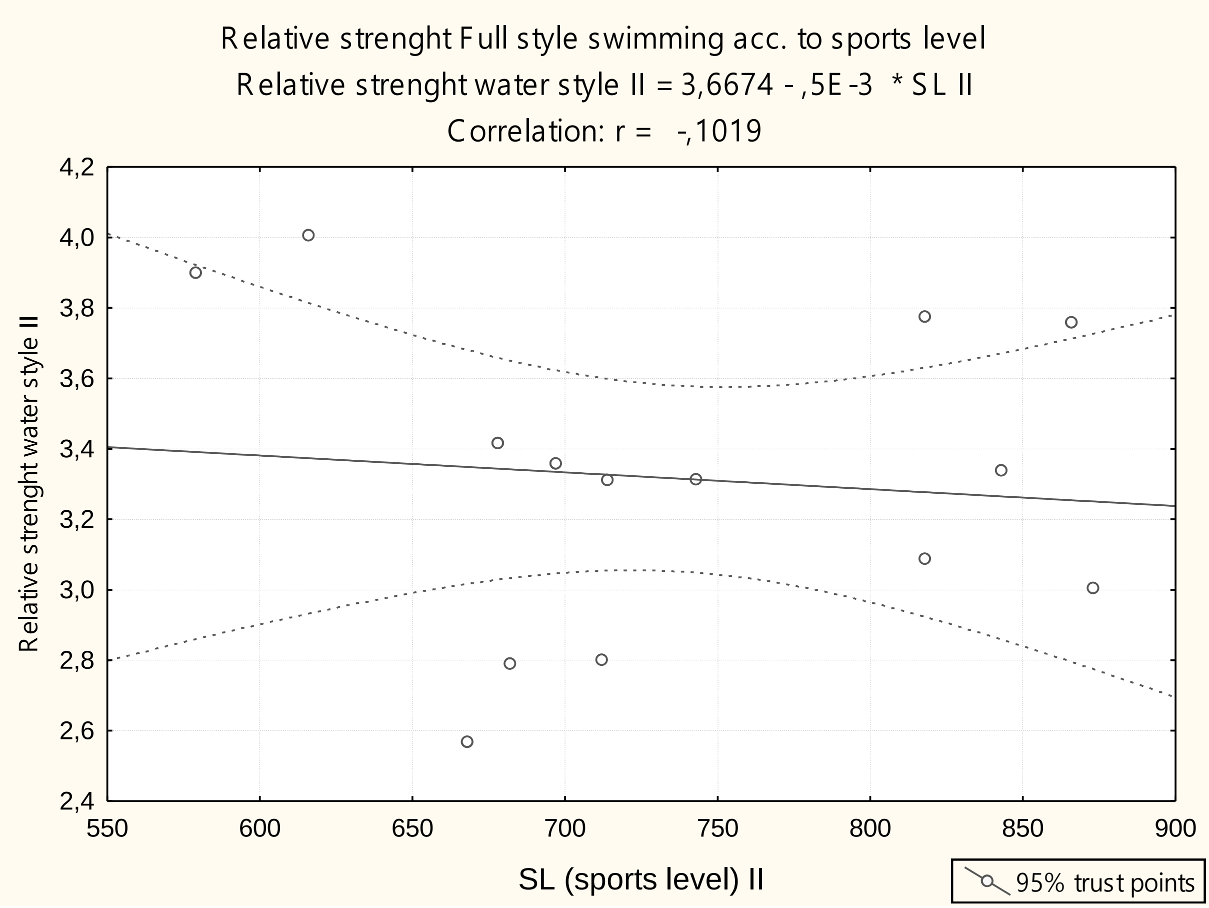

Diagram 4. Swimmers' sports level [in points] (n = 14) registered in September (test I) and March (test II), depending on the relative strength [N/kg] obtained during swimming with a full swimming style

CONCLUSIONS

1. The level of sports progress achieved by individual swimmers was greatly diversified.
2. The relatively high general and special strength resulted from their need to display these motor skills while swimming. Subjects who showed the greatest progress in the general and special strength trials, showed the biggest improvement in their swimming performance during the competition season.
3. Swimmers with a fairly high level of strength, but a moderate sports level should analyze and improve their swimming technique.
4. Subjects whose progress in general and special strength tests was the least significant, should try and achieve progress by developing other technical and coordination skills.

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