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# SELECTED TRAINING STRATEGIES TO IMPROVE PERFORMANCE IN MEN'S SPORTS SWIMMING

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**Abstract** The main aim of study was to identify effective strategies to increase the endurance and stamina of professional swimmers, thereby enhancing their overall performance in long-distance or endurance swimming competitions. The study included 21 participants from swimming clubs with a mean age of 17.34 ±2.51 years. The age range was 15 to 26 years, with varying height (172 cm to 196 cm) and weight (54 kg to 87 kg). The comprehensive study included anthropometric and isokinetic measurements, as well as training assessments analysed using statistical methods. Statistically significant changes were observed in the right arm (159.22% to 178.52%) and left arm (149.13% to 169.08% and 40.20%). There was a statistically significant improvement of 22.5 % in the left arm only straightening movement. The study's conclusions emphasise the importance of high-intensity exercises between 80% and 100% of maximum capacity to increase speed and power. These exercises should include significant resistance (70% to 90% of maximum load) and a limited range of repetitions (1 to 10). To develop strength and endurance, workouts should mirror the pace of a typical distance swim, incorporating moderate loads (45% to 80% of maximum body weight) and a greater range of repetitions (20 to 200).

**Key words:** swimming, endurance, strength, performance

## Introduction

The development of swimming as a sport has been influenced by new swimming techniques, modern sports facilities and sports associations and unions, but also by successive record-breaking performances (Lipoński, 2006; Nadobnik & Wiażewicz, 2022), but the logistic curves provide evidence that swimming records experienced a period of "accelerated" growth during the 1960–1970s and are now beginning to plateau (Nevill et al., 2007). Sport swimming is a very demanding sport. Training sessions last 5 or even 7 days a week and often twice a day. The average daily training volume ranges from 6.000 m to 10.000 m and more (Feijen et al., 2020). It should be assumed that athletes make an average of 8 to 10 shoulder movements over a distance of 25 meters, this means that they make about 30.000 rotations of each shoulder joint per week. This puts a significant strain on the shoulder girdle (Heinlein & Cosgarea, 2010). Daily swimming training of many hours of about more than 1 million times per annual cycle (Johnson et al., 2003) may influence the pathogenesis of swimmer's shoulder caused by repetitive swimming movements (Struyf et al., 2017; Sein et al., 2010).

Swimming at a high professional sporting level requires athletes to have somatic predispositions, such as body composition and structure (Hibberd et al., 2016; Shimura et al., 2021). Studies highlight the importance of these physical characteristics in enhancing performance and reducing the risk of injury (Zwierzchowska et al. 2023; Czabański et al., 2003). Depending on the distance, athletes rely on different energy sources during the effort. The configuration of a swimmer's energy utilization pattern should be tailored to the specific race distance in which the athlete specializes, know how the different energy systems (aerobic, anaerobic, lactate threshold) are engaged depending on the intensity and duration of the swim. It is the job of coaches to adapt training to optimise energy use for specific race distances (Guignard et al., 2019; Lorens et al., 2011).

The selection of male athletes is based on factors such as body proportions, height and relatively low body mass, smooth musculature, fine bone structure, adequate length and width of hands and feet, compatible calendar and biological age, high level of motor coordination according to the Rohrer index and high vital lung capacity, large range of motion in the shoulder and ankle joints (Jurimae et al., 2007; Maszczyk et al., 2011; Swanik et al., 2002; Seifert & Chollet, 2009). Talent, interest in swimming, diligence and good health also play a huge Role (Wiażewicz, 2015). Therefore, it would be appropriate to ask what methods should be used to improve sports performance in men's swimming. In this article, the authors, by conducting scientific research, try to answer this research question.

Many researchers confirm the need to modify training programmes to achieve the best athletic

Performance (Batalha et al., 2015; Morouęo et al., 2011a). Not only training in water, but also training on land is very important because it can result in improved arm performance in athletes (Morouęo et al., 2011b; Alonso-Cortes et al., 2006). Such training leads to an even development of the body by athletes (Ikeda et al., 2002). In contrast, specialised strength training improves muscle balance around the shoulder joint (Rzepka, 2012). In the provided article, the research encompassed a comprehensive set of approaches, including a literature review, gathering and examining demographic data and swimming performance results, as well as conducting anthropometric and isokinetic measurements. Furthermore, the study involved assessing generated graphs, evaluating the efficacy of training interventions, and performing statistical analyses on the acquired data. Various research methods were employed, such as observation, examination of individual cases, experimental techniques, statistical analysis, document analysis, interviews, and measurements, as relevant to the specific research methods used. In order to make a more detailed inference about the force in the shoulder joints, an analysis of the straightening torque variation curves generated from the collected data was performed. Torque was analysed over the 180-0° movement range. The analysis of the torque distribution data in the righting movement at the shoulder joint follows (Ciosek et al., 2015; Łubkowska & Troszczyński, 2011; Biodex, 2018).

We hypothesised that in order to increase swimmers' speed and power, it is necessary to exercise at a level close to the athlete's maximum capacity with a limited number of exercise repetitions. In contrast, to increase strength and endurance, a moderate load is sufficient, but with an increased number of repetitions of training exercises.

## Material and Methods

Prior to conducting the study, consent was sought from the Bioethics Committee of the Regional Medical Chamber in Szczecin Poland to conduct the study. The Commission gave such consent through its resolution No. 15/KB/V/2013. The study group consisted of 21 athletes of the Szczecin City Swimming Club (MKP), who held a sports class of the Polish Swimming Federation (PZP). In addition, they were to be at least 14 years old. Participants received dietary catering, which consisted of a personalised high-protein and high-carbohydrate diet to meet each athlete's specific nutritional requirements. The daily routine of the participants involved two training sessions, one in the morning and one in the afternoon. The lifestyle and nutrition of the subjects were comparable. The average age of the male participants was 17.34 ±2.51 years, with the oldest individual being 26 years old and the youngest six athletes aged 15 years. The average height of the athletes was 183.48 ±5.56 cm, ranging from the tallest at 196 cm to the shortest at 172 cm. The average weight of the subjects was 73.41 ±8.46 kg, with the highest recorded weight at 87 kg and the lowest at 54 kg. The mean training seniority was 10.34 ±2.8 years. The highest value of seniority was shown at 20 years, while the lowest value was 6 years. The athletes represented different classes. Among the athletes surveyed were world championships medalist; European championships finalist; European junior championships medalists, Polish championships participant, finalists and medalists; Polish junior championships finalists and medalists. The use of an isokinetic mode in the case of male athletes offered the possibility to control the speed of execution of a set movement. "Adjusting resistance" allowed the subject to increase the speed of the movement during the measurement, but no more than a preset value for the direction of movement (Moore at al., 2021). The flexion movement measurements encompassed the entire range of motion, starting from the position of maximum downward and backward extension of the joint and concluding at the point of maximum upward and backward flexion of the arm. Similarly, the measurements for straightening were conducted in the opposite direction. In total, each measurement generated 68 distinct strength parameter values for an individual, considering factors such as the limb's movement direction, the side of the body, and any disparities between the sides. A total of 4556 different values were collected during force measurements. The equipment utilized for this study was situated within the premises of the Biological Regeneration and Rehabilitation Centre at the Szczecin House of Sports (SDS) in Poland. An experimental approach was employed to assess the efficacy of an annual training program focused on strength training. These measurements were conducted on two occasions.

For the purposes of the study, the significance of the differences in the results of the individual strength parameters obtained in measurement one and two was analysed. An assessment of variable distributions was conducted. When the results of the Shapiro-Wilk test indicated that the distribution of variables in both measurements did not significantly deviate from normal (W > Critical value for 21 cases = 0.908 for men), a parametric Student's t-test for paired samples was employed. In cases where at least one parameter from either measurement significantly departed from a normal distribution (W < Critical value for 21 cases = 0.908 for men), the non-parametric Wilcoxon matched-pairs test was utilized. This test is the non-parametric equivalent of the Student's t-test for correlated variables. The presentation of results involved means ( ) and standard deviations (SD) or medians (Me) and interquartile ranges (R), contingent on the assessment of data distribution fitting normality (Łubkowska & Troszczyński, 2013; Skurvydas et al., 2008). For the statistical analysis of the variables, the differences between the sport score from measurement one and measurement two (AWS = WS2 – WS1) and the differences in the scores of the individual strength parameters between measurement two and measurement one (e.g. APT = PTII measurement – PTI measurement) were calculated. An analysis of the distributions of the variables was performed using the Shapiro-Wilk test. When the results of the Shapiro-Wilk test indicated that the distribution of both compared variables (differences) did not deviate significantly from the normal distribution (W > Critical value for 21 cases = 0.908 for men), r- Pearson correlation analysis was applied. In addition, the coefficient of determination ($R^2$) was calculated. If the result of the analysis of the distribution of at least one of the compared variables (differences) indicated that the distribution deviated significantly from the normal distribution (W critical value for 21 cases = 0.908 for men), rho-Spearman correlation analysis was performed (Wiażewicz, 2016).

## Results

In the annual training plan, technical exercises were planned for an average of 246.73 km, but the actual performance was 222.53 km. Shoulder muscle strength exercises had an average load of 448.16 km, with a typical performance of 402.24 km. In the men's group, joint range of motion (ROM) increased in the second measurement for both arms, with more than a 3° increase in the average score of the right arm in the first measurement. The left arm also showed an increase from 228.00 ±12.40° to 237.70 ±18.10° in measurement two, although not statistically significant (Table 1).

**Table 1.** Parameter: Joint Range of Motion (ROM) of the arm in the tested athletes

| | | | $W_{1\ x}$ | $W_{2\ xxx}$ | measurement I | measurement II | p |
|---|---|---|---|---|---|---|---|
| ROM | PR[1] (°) | (SD) | 0.953 | 0.985 | 236.98 (15.76) | 240.17 (20.30) | 0.4160 |
| | LR[2] (°) | Me (R) | 0.961 | 0.862* | 228.00 (12.40) | 237.70 (18.10) | 0.0582 |

ROM – parameter: joint range of motion; PR – right shoulder; LR – left shoulder; 1 – Wilcoxon's paired t-test was used. Student's t-test; 2 – Wilcoxon signed-rank test; $\bar{x}$ – arithmetic mean; SD – standard deviation; Me – median; R – quartile range; ° – degree, unit of measurement of plane angle; W1 – result of the Shapiro-Wilk test for the first measurement; W2 – result of the Shapiro-Wilk test for the second measurement; p – level of statistical significance; * – statistically significant result of the Shapiro-Wilk test, W < 0.908.

Men achieved a higher agonist:antagonist ratio (AG:AN) in measurement two, with a more than 2% increase for the right arm. There was also a trace increase of 0.1% in the AG:AN ratio for the left arm in the second measurement, but these changes were not statistically significant (Table 2).

**Table 2.** Parameter: Agonist to Antagonist Ratio (AG:AN) of the arm in the tested athletes

| | | | $W_1$ | $W_2$ | measurement I | measurement II | p |
|---|---|---|---|---|---|---|---|
| AG:AN | PR[2] (%) | Me (R) | 0.576* | 0.435* | 76.2 (25,8) | 78.4 (8,5) | 0.4140 |
| LR[2] (%) | Me (R) | 0.618* | 0.413* | 78.5 (24.3) | 78.6 (9.5) | 0.2971 | |

AG:AN – parameter: agonist to antagonist ratio; PR – right arm; LR – left arm; 2 – Wilcoxon matched pairs test applied; Me – median; R – quartile range; % – percentage; W1 – Shapiro-Wilk test result for measure one; W2 – Shapiro-Wilk test result for measure two; p – level of statistical significance; * – statistically significant result of the Shapiro-Wilk test, W < 0.908.

Peak torque (PT) increased in both arms for men in flexion and extension movements. In the right arm flexion movement, PT increased by almost 6 Nm (*P* = 0.0073), and in the right arm straightening movement, there was an increase from 74.32 ±19.46 Nm to 80.52 ±18.44 Nm (*P* = 0.0415). The left shoulder also showed an increase in PT in both movements, but these changes were not statistically significant (Table 3).

**Table 3.** Parameter: Peak Torque (PT) in flexion and extension movements of the of the arm in the tested athletes

| | | | | $W_1$ | $W_{2\ xx}$ | measurement I | measurement II | p |
|---|---|---|---|---|---|---|---|---|
| PT | bending | PR[1] (Nm) | (SD) | 0.948 | 0.965 | 59.26 (12,67) | 65.15 (15.55) | 0.0073** |
| | | LR[2] (Nm) | Me (R) | 0.935 | 0.895* | 58.00 (16.60) | 60.20 (14.30) | 0.1808 |
| | | scarcity[2] (%) | Me (R) | 0.803* | 0.848* | 6.90 (8.80) | 8.90 (7.70) | 0.6143 |
| | straightening | PR[1] (Nm) | (SD) | 0.957 | 0.914 | 74.32 (19.46) | 80.52 (18.44) | 0.0415** |
| | | LR[1] (Nm) | (SD) | 0.933 | 0.941 | 71.74 (19.52) | 75.92 (19.59) | 0.2283 |
| | | scarcit [2] (%) | Me (R) | 0.913 | 0.883* | 7.60 (11.70) | 6.30 (13.80) | 0.9032 |

PT – parameter: peak torque; PR – right arm; LR – left arm; 1 – Student's t-test was used; 2 – Wilcoxon signed-rank test was used; $\bar{x}$ – arithmetic mean; SD – standard deviation; Me – median; R – quartile range; Nm – newton meter, unit of torque and torque unit; % – percentage value; W1 – Shapiro-Wilk test result for the first measurement; W2 – Shapiro-Wilk test result for the second measurement; p – level of statistical significance; * – statistically significant Shapiro-Wilk test result, W < 0.908; ** – statistically significant difference, p < 0.05.

Maximum repetition work (MRW) results were higher in measurement two, with a significant increase in the right arm flexion movement (almost 23 J, *P* = 0.0003) and the extensor movement (over 21 J, *P* = 0.0307). The left shoulder MRW in the flexion movement also increased significantly from 157.90 ±36.11 J in measurement one to 177.69 ±32.93 J in measurement two (*P* = 0.0026). In measurement two, athletes exhibited a slightly shorter time to peak torque (PT TIME) in the right arm flexion movement compared to measurement one. The left arm showed an almost twofold increase in PT TIME. A reduction in PT TIME during the straightening movement was observed for both arms, with statistical significance only for the left arm (*P* = 0.0015). The angle to peak torque attainment (PT ANGLE) in flexion was negative for both arms, while in extension, it was positive. In the straightening movement, the right arm showed a nonsignificant increase in PT ANGLE, whereas the left arm exhibited a significant 16° increase (*P* = .0091) in measurement two. Significant changes were noted in total work (TW) during flexion of both arms. The right arm had an almost 140 J improvement (*P* = 0.0031), and the left arm showed an almost 200 J improvement (*P* = 0.0125), leading to a decrease in the total work deficit (TW) between the test sides. Average power (AP) increased in both arms during flexion and extension movements in measurement two. The right arm's flexion movement score increased from 60.47 ±20.61 W in measurement one to 70.02 ±25.93 W in measurement two (*P* = 0.0018). Similarly, athletes in the left shoulder test demonstrated an increase from 59.04 ±20.33 W to 66.54 ±19.96 W (*P* = 0.0145) between the two measurements. In the second measurement, statistically significant changes occurred in average power (AP) during the straightening movement in both the right and left arms, with a negligible non-significant change in the average arm power deficit. Acceleration time (AT) changes were small and variable, with slightly higher values in the right arm flexion movement and a slight reduction in the left arm AT. Deceleration time (DT) in the flexion movement showed consistent results for the right arm and a slight increase in the left arm in measurement two. There was a trace reduction in DT during straightening movements for both arms. Average peak torque (APT) increased significantly in both flexion and extension movements for both arms. The right arm flexion movement showed a statistically significant change from 38.95 ±10.27 Nm in measurement one to 43.10 ±14.88 Nm in measurement two (*P* = 0.0180). Results for peak torque to body weight (PT/BW) ratio were higher in the second measurement, with a significant improvement in the right arm for both movements. Athletes achieved a significant increase in PT/BW ratio, from 81.50 ±14.40% to 89.10 ±16.56% in the right arm, and from 102.27 ±23.04% to 110.97 ±22.70% in the left arm, in measurement two. The left arm showed a slight improvement in the peak torque to body weight (PT/BW) ratio in both flexion and extension movements, but these changes were not statistically significant. In the work to body weight (W/BW) ratio measurement, athletes achieved overall increases, with significant changes observed in the right arm (from 159.22 ±41.49% to 178.52 ±48.88%) and the left arm (from 149.13 ±39.71% to 169.08 ±40.20%). Fatigue factor (WF) scores were higher in the second measurement for the right arm, but lower for the left arm. The athletes in the second measurement of the right arm scored a few per cent higher than in the first measurement. This was true for movements in both directions, but a statistically significant change only occurred for right shoulder extension: in measurement one, the value of the factor in question was 0.4 ±72.2 per cent, while in measurement two it was already 7.1 ±59.4 per cent ($P = 0.0129$). A slight reduction in the fatigue factor (WF) value for men was observed in the left arm test, both in flexion and extension movements.

## Discussion and implication

It was noted that almost all isokinetic variables obtained in the presented studies were higher in shoulder straightening movements than in flexion movements for both sides and speed. This is corroborated by data obtained among sports subjects, as well as the results of non-training subjects. Shoulder joint range of motion (ROM) among the male participants was greater than the normal value of 208–218°. The biomechanical characteristics of upper limb movements during swimming require significant mobility in the shoulder joint. However, hypermobility in the shoulder joint can also cause strength deficits and accelerated fatigue in internal rotation, which increases the risk of shoulder injury. The agonist-to-antagonist ratio (AG:AN) in study one was similar to the average value of 88–89% obtained in studies of Masters category swimmers.

Among swimmers, the mean values of this parameter were several to several per cent lower. Agonist to antagonist (AG:AN) ratios among athletes with dominant shoulder straightening movements, during training and during athletic competition, were reported to be 50% in baseball pitchers. In young players, the coefficient in question took on values of 88–92%. It should be borne in mind that increased joint stability is influenced by the maintenance of appropriate proportions of the strength of individual muscle groups. Peak torque (PT) values of the arms in both measurements, among the tested athletes, showed higher values, from a few to even several Nm in bending and in extending, about 48 Nm for bending and about 67 Nm for extending. This was the average for male, exclusively swimming sprinters. This confirmed the thesis of higher strength demands placed on sprinters. The value of the torque was able to change with the change of the preset angular velocity. The lower the preset angular velocity, the more torque could be produced in concentric contraction. Although many authors base their studies solely on the analysis of peak torque (PT) of the arm muscles, the inference should be extended to include the results of other strength parameters obtained by isokinetic measurement. Describing shoulder muscle characteristics solely by peak torque (PT) values may not be exhaustive. Acceleration time (AT) and deceleration time (DT) were the values of the time it took the subjects to reach the set angular velocity and to stop ($v = 0$) from the angular velocity. In this way, the neuromuscular abilities of the subjects to induce movement and to eccentrically control at the end of the range of motion were assessed. The lower the values of these parameters, the higher the neuromuscular abilities of the subject. The values of acceleration time (AT) and deceleration time (DT) of the athletes varied. Average peak torque (APT) is the quotient of the sum of the peak torque values of all repetitions performed during the test and the number of these repetitions. This parameter provided an opportunity to assess the ability of the muscles to maintain a high level of peak torque for all repetitions in the test. The peak torque to body weight (PT/BW) ratio in the men's group for the flexion movement took an average value at the lower limit of the norm, and for the extensor movement at its middle range. It should be added that these norms were created based on the results of non-trained individuals. The acceptable coefficient of variation (COV) for large muscle groups, which include the shoulder, is 15%. For male swimmers, the value of this variable was within normal limits and the results were similar to those of young swimmers – 10–12%, in a study on young swimmers, showed several percent higher values of this parameter for shoulder flexion – 24–25% and a negative value in the straightening movement, from about –8% to about –17%, compared to the results in the presented article.

## Conclusion

To improve speed and power, it is necessary to perform exercises at between 80% and 100% of the athlete's maximum capacity. Workouts should include significant resistance between 70% and 90% of maximum body weight and a maximum of 10 repetitions.

When focusing on building strength and endurance, it is necessary to match the pace to a typical swimming distance. This includes working with a moderate load, usually in the range of 45% to 80% of your maximum body weight and covering a number of repetitions between 20 and 200.

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