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Abstract

Introduction. Swimming is an athletic discipline that largely involves the upper limbs. Due to the driving and propulsive function, there is a heavy involvement of almost all muscles of the arm. Painful shoulder syndrome (PSS) is considered to be one of the main causes of interference with an effective and correct movement of the underwater stroke, which is a fundamental element of functionality in this discipline. The aim of this study was to evaluate whether PSS affects upper limb function in competitive swimmers. Material and methods. Thirty-two swimmers aged 17–24 years with at least 2nd sport class participated in the study. The swimmers were divided into two groups: group I – the experimental group, with subjects reporting pain in the shoulder area, and group II – the control group (sub-jects without pain in the shoulder area). Isokinetic tests at 60°/s, 180°/s, and 300°/s, hand grip strength tests, and upper limb power measurements on a swim ergometer were performed. The standard visual analogue pain scale (VAS) was used to assess the severity of pain. Results. There were significant relationships between hand grip and pulling force. Hand grip also strongly correlated with peak torque in all considered limb movements. The other examined parameters did not show statistical significance. Conclusions. Despite the significant results of the study component, there was no significant influence of painful shoulder syndrome on performance levels.

Keywords

painful shoulder syndrome, swimmers shoulder, upper limb function

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Article

Painful shoulder syndrome and upper limb function in competitive swimmers

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Abstract. Introduction. Swimming is an athletic discipline that largely involves the upper limbs. Due to the driving and propulsive function, there is a heavy involvement of almost all muscles of the arm. Painful shoulder syndrome (PSS) is considered to be one of the main causes of interference with an effective and correct movement of the underwater stroke, which is a fundamental element of functionality in this discipline. The aim of this study was to evaluate whether PSS affects upper limb function in competitive swimmers. Material and methods. Thirty-two swimmers aged 17–24 years with at least 2nd sport class participated in the study. The swimmers were divided into two groups: group I – the experimental group, with subjects reporting pain in the shoulder area, and group II – the control group (sub-jects without pain in the shoulder area). Isokinetic tests at 60°/s, 180°/s, and 300°/s, hand grip strength tests, and upper limb power measurements on a swim ergometer were performed. The standard visual analogue pain scale (VAS) was used to assess the severity of pain. Results. There were significant relationships between hand grip and pulling force. Hand grip also strongly correlated with peak torque in all considered limb movements. The other examined parameters did not show statistical significance. Conclusions. Despite the significant results of the study component, there was no significant in-fluence of painful shoulder syndrome on performance levels.

Keywords: painful shoulder syndrome, swimmers' shoulder, upper limb function.

1. Introduction

Swimming is one of the most widespread and most widely practiced forms of physical activity in the recreational aspect. It brings many health-promoting benefits and is recommended by many medical specialists, starting with corrective swimming for children with locomotor system disorders, such as scoliosis, foot defects, enlarged kyphosis, flat back, etc., through organized swimming classes for overweight people, pregnant women, aqua aerobics, and ending with water activities for seniors [1,2].

Competitive swimming, on the other hand, is considered to be one of the most monotonous and demanding sport disciplines. Training begins at an early age. In elementary school, children learn to swim in four styles: butterfly, backstroke, breaststroke and front crawl. In the following years, they improve their skills to become active competitors of sports clubs and start their sports careers. The age at which swimmers reach for the highest laurels of international competitions significantly differs. For example, 29-year-old Australian Petria Thomas won gold medal during the Olympic Games in Athens at a distance of 100 m butterfly style among women. At The same distance among men was claimed by a 10-year younger swimmer – Michael Phelps. Consequently, swimming is a discipline where training takes place over many years. The body must be appropriately adapted to the dimensions of the work performed for a long period of time, which is why young athletes are subjected to very intense, aerobic and anaerobic, training [3, 4].

Owing to the diversity in swimming styles and competitive distances, training regimens are tailored and vary according to the athlete's preferred event length, leading to the categorization of swimmers into sprint, middle-distance, and long-distance groups.

Sprint training, in particular, is distinguished by its focus on high-intensity workouts with a reduced overall volume. Athletes engage in shorter, yet faster-paced swims, emphasizing peak speed execution. A significant component of sprint training is dry-land conditioning, which is pivotal in enhancing muscular strength and power [5, p. 171–80], thereby complementing the aquatic aspects of the training regime.

The training of long-distance swimmers involves covering very long distances in water and is largely based on endurance training. Swimmers can cover up to 20 kilometers per day, and about 100 kilometers per week. Training takes place twice a day and lasts a minimum of 2 hours. Dry land exercises are also usually limited to strength and endurance training [5, p. 235–39].

There are general schemes for technical training depending on swimming style. For example, sprinters' work of the upper limbs is done with the so-called "straight arms" and involves putting as much force as possible into a given movement. Freestyle swimming for long-distance swimmers puts emphasis on the most economical movement: the work of the upper limbs is done with bending at the level of elbow joints [6].

Swimming is a sport that largely involves the upper limbs. Both the flexor and extensor muscles of the arm as well as the internal rotators in the backstroke style and the external rotators are heavily involved in the work. The upper limb in swimmers primarily serves a propulsive function [7].

On average, a long-distance swimmer makes about 4000 movements with one upper limb during a single workout [8]. By performing this large number of repetitive movements, shoulder joint pain is one of the most common musculoskeletal complaints among swimmers.

The prevalence of shoulder pain in swimmers has shown a linear increase over the following decades [9, 10]. Shoulder pain is particularly frequent, and, with the reported prevalence rates of as high as 91%, it is a major cause of missed practice [9, 10]. Allegrucci et al. [11] reported that between 40 to 69% of the swimmers complain about pain; McMaster [12] indicated up to 68%, and Bak (2010) reported 65%. These statistics underscore the substantial impact of painful shoulder syndrome (PSS) among swimmers, highlighting its potential to significantly impair upper limb function.

PSS is a disorder that affects sports in which the upper limbs are forced to do a lot of work (volleyball, handball, and swimming). PSS can be caused by many factors: damage to muscles, ligaments or tendons. It usually arises when performing an unexpected and ill-considered movement, jerking, or is a result of insufficient warm-up, or performing exercises with too much load [9, 12].

Within the swimming community, PSS may emerge due to suboptimal swimming techniques. Additionally, the condition often stems from excessive training loads that surpass the muscles' strength and endurance capacities. Excessive reliance on hand paddles during training, aimed at augmenting stroke power, can also contribute to the overloading phenomenon, further exacerbating the risk of developing PSS. Moreover, changes in neuromuscular control of the stabilizers of the shoulder girdle may occur as a result of a break in training [8, 14].

According to Jobe's hypothesis, due to repetitive movements in the shoulder joint, swimmers develop a chronic microtrauma that causes a lack of tightness in the shoulder com-plex which can lead to mild instability and eventually cause mechanical damage [15]. We need to consider a protective neuromuscular response in the body, which limits movement to avoid further pain or damage [16].

PSS in swimmers may also be caused by the tendinopathy of the supraspinatus muscle, which is responsible for protecting the head of the humerus in the glenoid fossa [17]. One of its most common causes is repetitive microtrauma due to overloading of this muscle. PSS symptoms include pain, swelling, restriction of the range of motion, which may limit the number of workouts or, if the problem persists, eventually lead to the complete abandonment of professional sports.

PSS in swimmers can also be found in literature under the name of swimmer's shoulder. It was first described by Kennedy and Hawkins in 1974 and defined as a painful condition resulting from frequent repetitive movements of the upper limb among swimmers. It is not a generally accepted clinical diagnosis, but rather is caused by one of the following possible factors: subchondral tightness syndrome, rotator cuff tendinopathy, disorders originating from the long head of the biceps brachii muscle, instability of the shoulder joint, or injury to the clavicle [18].

Swimmers suffering from painful shoulder syndrome often modify their techniques to sidestep the motions that trigger discomfort, striving to maintain their training regimen, and it is well known that regularity is one of the fundamental elements of swimming. Every missed workout distances the athlete from their goal. For this reason, swimmers with painful shoulder syndrome adjust their swimming technique and, as mentioned be-fore, inadequate or poor technique may lead to PSS, which opens a door to a vicious circle [17]. The hand of an athlete with pain comes out of the water much faster making the movement shorter and less effective. Pain interferes with an effective and properly executed underwater stroke movement, which is a fundamental element of upper limb functionality during swimming.

The purpose of this study was to evaluate whether PSS affects the upper limb function in competitive swimmers. We hypothesized that swimmers with PSS might perform differently and achieve lower results in tests compared to the control group. In addition, we wanted to check whether there is a relationship between hand grip strength and pulling strength with peak torque and power in the study groups. The decision to investigate these parameters was also motivated by the existing gap in the scientific literature.

Investigating the upper limb function in competitive swimmers with painful shoulder syndrome is not only imperative for enhancing our understanding of the impact of this condition on athletes but also for advancing sports science, improving athlete care, and optimizing performance outcomes.

2. Materials and methods

2.1 Participants

Thirty-two athletes (13 females and 19 males) aged between 17 and 24 years (mean age 18.9 years) participated in the study. Further characteristics of the group are available in Table 1. Participation was voluntary. All subjects trained in swimming sports clubs. Swimming training took place at least 10 times a week and lasted at least 90 minutes. Additionally, they participated in sports training camps and competitions at the national and international level several times a year. Dryland training (motor, strength) took place at least 4 times a week and lasted at least 45 minutes (one training unit). The athletes participating in the study held more than 670 FINA points in their best event. Participants were in the pre-season phase. The participants were assigned to two groups. The first one, the experimental group (I) consisted of 13 athletes (5 women and 8 men) who reported pain in the shoulder area. The second one – the control group (II) consisted of 19 athletes

(8 females and 11 males) with no previous complaints of shoulder pain. The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Wroclaw University of Health and Sport Sciences.

Table 1. Characteristics of the swimmers in the control group (n = 19) and the experimental group (n = 13).

Characteristic	Group	Mean ± SD
Height [cm]	control	178.6 ± 10.7
	experimental	181.0 ± 8.7
Weight [kg]	control	67.5 ± 10.9
	experimental	72.5 ± 10.6
BMI [kg/m^2]	control	21.2 ± 1.9
	experimental	22.7 ± 1.9
WHR	control	0.786 ± 0.039
	experimental	0.793 ± 0.074

SD – standard deviation; BMI – Body Mass Index; WHR – Waist-Hip Ratio.

2.2 Assessments

The study was conducted in the Internal Medicine Laboratory and the Aquatic Research Laboratory, at Wroclaw University of Health and Sports Sciences. The following examinations were carried out:

– pain assessment – VAS scale,

– hand grip strength [kg],

– pull test on a swimming ergometer [kg],

– upper limb strength tests (flexor and extensor muscles) in isokinetic conditions: peak torque [N-m], average power [W].

Pain assessment – VAS scale

Each participant underwent assessments following a consistent sequential protocol. A standard visual analogue pain scale (VAS) was used to assess the severity of pain. The athletes indicated the pain intensity on a scale from 0 – no pain at all to 10 – unbearable pain. We used a scale of 0–10 for the study, but it was in mm, which is 0–100 mm. The studies suggested that 100–mm VAS ratings of 0 to 4 mm can be considered no pain; 5 to 44 mm, mild pain; 45 to 74 mm, moderate pain; and 75 to 100 mm, severe pain. A higher score indicated a greater pain intensity. Subjects indicated the level of pain on a scale presented to them visually.

Hand grip strength

The hand grip strength of each athlete was measured using a SAEHAN SH5001 hydraulic hand dynamometer. Each subject was informed in advance how to perform the test correctly. The test subject embraced the dynamometer comfortably so that the fingers and hand adhered closely. Then they lowered the upper limb along the trunk and at a distance from the body (so that neither the elbow nor the hand touched the body) and squeezed the dynamometer with maximum force. The procedure was repeated twice, with a one-minute rest between trials, and the result was the average of the two measurements given in kilograms [kg] [19, 20]. The measurement of hand grip strength was always made under the same conditions and with the same dynamometer for all swimmers.

Swimming ergometer pull test

The swimming stroke force was measured on a VASA Swim Bench ergometer (Vasa, Inc., Essex Junction, VT, USA). After stabilizing the swimmer's body, the swimmer performed three maximal strokes simulating a butterfly style movement (two upper limbs simultaneously). The procedure was repeated three times, with a one-minute rest between trials, and the best result was taken for analysis. The best stroke score was considered out of three. The results were given in kilograms [kg].

Examination of Force–Velocity Parameters

The measurements were made using a Multi Joint 4 dynamometer (Biodex, Shirley, NY, USA). It is a non-invasive method using an isokinetic mode and gives reliable numerical data [20]. Functional assessment of flexor and extensor muscles on the shoulder joints was performed in all subjects. Before each test, the chair and dynamometer and the appropriate attachment were positioned so that the tip of the dynamometer was an extension of the axis of rotation at the joint under study. The subject's trunk and pelvis were stabilized. The stabilization system allows freedom of movement in the shoulder joint in the sagittal plane from 60° of extension to approximately 150° of flexion. The range of motion for extension and flexion of the upper limb at the shoulder joint was set using a control panel, followed by verbal instruction and a test.

The test consisted of warm-up movements – the subject performed 3 submaximal flexion and extension movements at each shoulder joint and 1 maximal movement to get familiar with the load, and the main part – measurement of force moments at different angular velocities, 60°/s, 180°/s and 300°/s.

At an angular velocity of 60°/s – the subject performed 5 repetitions, while at an angular velocity of 180°/s – 10 repetitions, and at an angular velocity of 300°/s – 15 repetitions. The parameters analyzed included peak torque [Nm] and average power [W]. There was a one-minute rest between the tests. The task was to generate the maximum muscle force in the shortest possible time in each movement.

2.3. Statistical analysis

Statistical analysis was performed using the STATISTICA 10 (StatSoft) program. The hypothesis of normal distribution for the considered traits was verified using the Kolmogorov-Smirnov test. Since the null hypothesis of normal distribution was not rejected, parametric statistics were employed in further analysis. Statistical description included the determination of mean values, standard deviations and the range of variability of the analyzed characteristics (minimum and maximum values). Comparison of mean values in the experimental and control group was performed using Student's t-test for independent samples. Relationships between traits were assessed using r-Pearson linear correlation coefficient. The statistical significance of correlation coefficients was evaluated using Student's test for correlation coefficient. A significance level of $p < 0.05$ was assumed, while statistical significance at $p < 0.01$.

3. Results

3.1. VAS scale

The mean score on the VAS pain rating scale in the control group was 1.69, which can be considered no pain. In the experimental group, the mean score on the VAS scale was 42, which covers the mild pain range.

3.2. Upper limb tests

The mean hand grip [kg], as well as the mean pull force scores [kg], obtained on the swim ergometer were higher in the experimental group. The differences in the mean values in the two groups were statistically insignificant (Table 2).

Table 2. Distribution parameters of hand grip and pulling strength in the experimental and the control groups.

Test	Side	Group	Mean	Min–Max
Hand grip [kg]	right	control	39.7±12.1	18.0–59.0
		experimental	42.1±11.4	28.0–62.0
	left	control	38.2±10.06	20.0–54.0
		experimental	41.4±12.2	24.0–62.0
Pull strength [kg]	right	control	1.743±0.447	0.84–2.54
		experimental	1.912±0.410	1.35–2.81
	left	control	1.724±0.427	0.80–2.50
		experimental	1.859±0.417	1.20–2.84

No statistically significant differences were found between the experimental and the control groups in the distribution of peak torque values [N-m] in all considered types of upper limb movement (Table 3).

Table 3. Parameters of peak torque distribution in the experimental and control groups.

Movement type	Side	Angular velocity [°/s]	Group	Peak torque [Nm] Mean ±SD	Min–Max	*p*
Flexion	left	60	control	64.43 ± 21.88	27.5–105.3	0.705
			experimental	67.56 ± 24.08	36.7–118.9	
		180	control	66.48 ± 17.80	40.7–106.2	0.706
			experimental	64.06 ± 17.53	42.7–101.8	
		300	control	71.72 ± 21.55	34.9–117.5	0.463
			experimental	77.26 ± 19.33	49.0–108.7	
	right	60	control	64.23 ± 22.81	33.3–97.9	0.574
			experimental	69.11 ± 25.32	37.8–129.3	
		180	control	65.78 ± 20.69	35.4–103.5	0.834
			experimental	67.47 ± 24.18	46.4–135.8	
		300	control	71.49 ± 21.82	30.8–116.7	0.471
			experimental	77.38 ± 23.18	43.7–119.6	
Extension	left	60	control	84.53 ± 26.61	38.1–122.1	0.345
			experimental	95.44 ± 37.78	63.8–182.0	
		180	control	77.34 ± 25.63	32.2–113.5	0.597
			experimental	82.72 ± 31.27	51.1–155.8	
		300	control	80.10 ± 25.03	37.9–121.2	0.171
			experimental	93.78 ± 29.92	39.0–146.8	
	right	60	control	85.72 ± 27.67	40.7–127.2	0.285
			experimental	97.65 ± 34.15	53.5–173.7	
		180	control	77.64 ± 29.27	33.3–121.0	0.685
			experimental	81.79 ± 26.44	45.9–135.5	
		300	control	77.69 ± 28.22	41.1–128.2	0.349
			experimental	86.76 ± 23.65	45.4–131.7	

Similarly, there were no statistically significant differences between the experimental and the control group in the distribution of average power [W] in all considered types of upper limb movement (Table 4).

Table 4. Parameters of the average power distribution in the experimental and control groups.

Movement type	side	Angular velocity [°/s]	Group	Average Power [W] mean	Min–Max	p
FLEXION	left	60	control	49.19 ±19.29	20.1–84.9	0.667
			experimental	52.32±21.07	26.7–98.3	
		180	control	92.62±40.11	33.4–158.8	0.936
			experimental	91.55±31.28	43.0–150.3	
		300	control	96.96±43.20	31.5–167.5	0.682
			experimental	91.22±30.27	44.6–147.6	
	right	60	control	50.16±19.45	21.6–79.8	0.499
			experimental	55.28±22.63	25.5–110.4	
		180	control	92.96±41.05	33.8–157.4	0.854
			experimental	95.62±37.69	43.7–185.1	
		300	control	97.41±41.43	31.3–171.2	0.835
			experimental	100.53±41.15	43.3–193.4	
EXTENSION	left	60	control	63.09±21.12	25.1–92.8	0.417
			experimental	71.02±33.48	43.7–149.5	
		180	control	126.40±54.51	32.2–203.1	0.495
			experimental	141.80±71.57	43.5–299.0	
		300	control	136.26±65.72	44.1–244.9	0.636
			experimental	148.78±82.19	33.9–311.4	
	right	60	control	63.52±22.89	28.8–104.4	0.355
			experimental	71.82±26.87	36.6–126.6	
		180	control	123.18±61.81	35.0–222.6	0.678
			experimental	132.06±54.08	62.7– 222.6	
		300	control	131.83±79.78	25.9–262.7	0.593
			experimental	145.84±58.67	44.5–238.4	

Significant correlations were found between hand grip and pulling strength. These correlations were similar in the experimental and control groups, but the analyzed material did not allow us to show that the PSS can affect the magnitude of correlations of these features (Table 5).

Table 5. Correlation of hand grip and pulling strength.

Group	Upper limb	r–Pearson's correlation	
		R	p
experimental	right	0.742	0.003
	left	0.836	0.0003
control	right	0.760	0.0002
	left	0.871	0.000001

Hand grip strongly correlated with peak torque in all considered limb movements in the experimental and control groups (Table 6). All determined correlations were statistically significant ($p < 0.001$).

Table 6. Correlations of hand grip with peak torque.

Upper limb	Movement type	angular velocity[°/s]	r–Pearson's correlation	
			Experimental group	Control group
Right	flexion	60	0.812	0.921
		180	0.811	0.867
		300	0.811	0.823
	extension	60	0.845	0.957
		180	0.891	0.954
		300	0.764	0.887
Left	flexion	60	0.875	0.784
		180	0.699	0.747
		300	0.730	0.687
	extension	60	0.897	0.937
		180	0.908	0.947
		300	0.778	0.862

The hand grip strength strongly correlated with the mean power in all considered limb movements, both in the experimental and the control group (Table 7). All determined correlations were statistically significant (p<0.001).

Table 7. Correlations of hand grip with average power.

Upper limb	Movement type	Angular velocity [°/s]	r–Pearson's correlation	
			Experimental group	Control group
Right	flexion	60	0.850	0.917
		180	0.821	0.921
		300	0.854	0.903
	extension	60	0.897	0.930
		180	0.820	0.932
		300	0.856	0.859
Left	flexion	60	0.895	0.783
		180	0.901	0.823
		300	0.833	0.843
	extension	60	0.882	0.966
		180	0.897	0.925
		300	0.918	0.924

The correlations of the pulling strength with the peak torque were high and statistically significant ($p < 0.01$) in all considered movements of the upper limb, both in the experimental and the control group (Table 8). PSS had no clear effect on the correlation of these characteristics.

Table 8. Correlations of pulling strength with peak torque.

Upper limb	Movement type	angular velocity [°/s]	r–Pearson's correlation	
			Experimental group	Control Group
Right	flexion	60	0.859	0.637
		180	0.748	0.717
		300	0.635	0.642
	extension	60	0.753	0.834
		180	0.757	0.797
		300	0.597	0.630
Left	flexion	60	0.894	0.670
		180	0.768	0.615
		300	0.652	0.580
	extension	60	0.876	0.822
		180	0.913	0.799
		300	0.800	0.626

Also, a high and statistically significant correlation of pulling strength [kg] with average power [W] occurred in both groups (Table 9).

Table 9. Correlations of pulling strength with average power.

Upper limb	Movement type	Angular velocity [°/s]	r–Pearson's correlation	
			Experimental group	Control group
Right	flexion	60	0.869	0.638
		180	0.877	0.706
		300	0.905	0.660
	extension	60	0.770	0.763
		180	0.725	0.706
		300	0.632	0.596
Left	flexion	60	0.884	0.693
		180	0.883	0.707
		300	0.779	0.705
	extension	60	0.877	0.835
		180	0.886	0.735
		300	0.836	0.714

4. Discussion

Much of the study on PSS in swimmers involves consideration of the cause. The accurate identification of the problem and having a proper diagnosis if any pain appears is a key to being successful not only in treatment but also in prevention of possible future injuries. Davis et al. introduce a broad spectrum of possible causes of shoulder problems in swimmers following with differential diagnosis and treatment possibilities [22]. Muscle strength imbalances between the internal and external rotators of the shoulder are frequent in swimmers. Drigny et al. showed a promising tool for prediction of shoulder injuries in elite swimmers based on the issue mentioned above [23]. Jobe's hypothesis states that the main reason for this problem is excessive mobility in the shoulder [15]. De Martino and Rodeo [24] indicate that shoulder excessive laxity and muscle imbalance are crucial

PSS factors in swimmers. Another major cause of PSS is shown in a study by Sein [17], whose results show that tendinopathy of the supraspinatus muscle is responsible for painful shoulder syndrome. Also in Sein's study, the correlation between the occurrence of supraspinatus tendinopathy and the athlete's sport class, the number of training hours per week, and the amount of distance swum per week was examined. Athletes who swam more than 15 hours per week had twice as high the risk of supraspinatus muscle tendinopathy, and the risk for swimmers who swam more than 35 kilometers per week was four times higher [17]. The results were statistically significant, which was associated with an increase in the risk of PSS as the athletic career progressed. In the conducted study, a distinction between sprinters and long-distance runners was not made due to insufficient sample size. In another study, it is underlined that the function and the structure can be altered due to pain disabling master swimmers [25].

Tovin in his article describes the changes that should occur in swim training when shoulder pain occurs, which are: reducing training frequency and distance, minimizing shoulder load by using fins, excluding swim lunges and planks from training, and changing style habits by eliminating errors that cause shoulder pain such as: improving body position in the water, improving body rotation, modifying hand motion underwater, and changing the hand entry element of the water [8].

If there is a necessity to undergo a physical therapy program, there are a few studies that suggest an individual approach based on specific swimming style [27]. Tovin [8] shows which elements should receive special attention. The rehabilitation plan should be comprehensive and include not only the affected element, but also the following should be considered: strengthening of the rotator cuff, strengthening of the stabilizers of the scapula, i.e. primarily the anterior cingulate muscle, stretching of the thoracic muscles [8].

Almeida et al. [18] created a rehabilitation program for athletes with painful shoulder syndrome. The program involves four stages. The first one includes manual therapy, shoulder joint mobilization, trigger point therapy, and isometric exercises. The second stage includes stabilization and stretching exercises. The third stage includes the previous techniques to which strengthening exercises are added. The fourth stage is an indication of return to full function and return to training. Scores are given on a 0–10 analogue scale, with a mean of 9.5 at the beginning of the study with an end of 0. Kibler and Swanik [28, 29] in their study suggest that people with PSS should perform open chain exercises during rehabilitation, and after the rehabilitation period plyometric exercises should be introduced into sports training to improve proprioception.

The psychological aspects of competitive sports must also be mentioned. The is-sue of athletes' psychological realm could also be relevant and could affect the results of the study. Many researchers confirm that athletes have higher pain tolerance than non-athletes [30]. In our own study, a pain rating scale questionnaire was administered and resulted in a low mean pain scale score in the control group (VAS = 1.69). In the sample's own assessment, the mean score on the VAS pain rating scale in the experimental group was 42, which is in the mild pain range.

The swimmers participating in the experimental group approached it with commitment. They may have understood the study as a form of challenge to themselves, which caused the release of hormones that block the perception of pain. It is worth mentioning that during the study none of the athletes in the experimental group complained about the pain in the shoulder area, whereas after a few hours the pain did appear.

O'Donnell also pays attention to the psychological aspect of the athlete and advises that the swimmer should not be "cut off" from the training group or excluded completely from training, but that upper limb stress should be relieved by the use of fins during training or completely excluded by introducing exercises involving only the lower limbs [29].

Our study was designed to evaluate upper limb function in competitive swimmers with painful shoulder syndrome. The mean test scores were non-significantly higher in the experimental group. This may be due to the fact that individuals in this group did not have the acute phase of painful shoulder syndrome and were able to follow their regular training schedule. Their pain condition did not result in exclusion from training. On the other hand, qualifying subjects with acute PSS would have prevented participation in the study due to their inability to perform the movement.

Our own research shows a very high correlation between the components of the study, but this is not statistically significant between the experimental and the control group. This may be because the research material was too small for the results to be statistically significant, so it would be worth repeating the study on a larger number of subjects.

Bak and Magnusson [27] compared arm strength and the range of motion at the shoulder joint in swimmers without painful shoulder syndrome and in those with the syndrome. They demonstrated that swimmers with painful shoulder syndrome achieved lower peak moment and strength at the shoulder joint than those who were pain-free.

The prevalence of painful shoulder syndrome in swimmers by style preference is another area for research. Unfortunately, in our study, due to a too small group of subjects, the breakdown by style specification and preferred distance was not conducted either. There is little information in the literature regarding specialized preventive exercises for style specification, which may be of great importance in avoiding shoulder injuries in swimmers. However, the need of unifying trainers' approach and creating clear protocols for treatment in case of injury are still in the scope of scientific interest [32–34].

Most of the correlation coefficients in the study group had values that were smaller than the values of the corresponding coefficients in the control group. However, one of the limitations of this study is the small size of both groups (13 and 19 subjects) and thus the inability to consider these differences as statistically significant. The possible influence of PSS on the decreased correlation of handgrip strength with peak torque needs to be verified on a much larger sample.

This study proved many statistically significant correlations between its individual components. There is a high correlation between hand grip strength and peak torque. However, no studies were found showing these correlations in the upper limb, while there are many studies on the correlation between hand grip measured by a dynamometer and peak torque at the knee joint. There are also some studies focusing on association between grip and global muscle strength or isokinetic muscle function [35–37]. Horsley et al. found a strong correlation between grip strength and lateral rotator strength, suggesting that assessment of grip strength could be used as a rotator cuff monitor of recruitment function [38]. The hand grip-measuring device is very simple to use, useful for testing hand function and capacity and widely used to test comprehensive muscle strength at upper extremity. The result of measurements of hand grip and manual muscle testing of the upper extremity shows high correlation to the hand, shoulder and elbow joint [39]. The study by Sathya et al. shows that grip strength testing could be used as a predictor for shoulder power [40]. Also, the hand grip power and the maximum contractile force of the shoulder rotation of spinal cord injury patients show a very high level of correlation [41]. In rehabilitation, it is widely accepted that effective muscle action on distal joints can be achieved when proximal joints are efficiently stabilized by the surrounding structures [42]. Therefore, the link between proximal stability and distal mobility could explain the relationship between handgrip strength and rotator cuff strength [43]. Several interventional studies supported this link and reported a significant increase in grip strength with increased shoulder stability [44]. Cakir-Atabek's study shows relationships between hand squeeze force and peak torque at the knee joint in female handball players [45].

Our study showed highly significant relationships between hand grip strength and peak torque in the experimental and control groups.

Limitations

The study should be continued with a bigger sample size. In future studies, we will use an algometer and standardized questionnaire like The Shoulder Pain and Disability Index (SPADI) to examine pain. Moreover, studying a particular swimming style and distance could also be very informative. Our aim is also to use more advanced technology, like EMG, to profoundly investigate PSS in swimmers.

5. Conclusions

This study was designed to assess the upper limb function in competitive swimmers with PSS. The test results were non-significantly higher in the experimental group. PSS swimmers performed the tests on similar levels compared to the control group. There was no significant effect of painful shoulder syndrome on performance. There are strong relationships between handgrip strength and peak torque and power in both the experimental and the control group. Among the many laboratory tests used in this study, it has been shown that strength tests with dynamometry have the strongest relationship with the pulling strength.

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