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Swimmers' shoulder injury prevention by correctly evaluating technical errors

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Dictionary:

Shoulder injury/problem – as either pain or a diagnosed injury in the shoulder [18].

Technique – specific procedures to move one's body to perform the task that needs to be accomplished [63].

Technique– noun a way of performing an action [64].

Exercise intensity – jn order to improve physical fitness, exercise must be hard enough to require more effort than usual. The method of estimating appropriate training intensity levels varies with each fitness component. Cardiovascular fitness, for example, requires elevating the heart rate above normal [65].

General swimmer characteristics – included the swimmers' anthropometric characteristics, the length of time they have been competing, the training load, and whether they had taken a break in their swimming career at any point [66].

Counterproductive – from praxeological perspective certain action can be: productive – non-productive – counterproductive – neutral. The action is counterproductive when a doer achieved goal opposite than intended [67, p. 220]

Abstract:

Background and Study Aim: Shoulder pain is common in young swimmers. The aim of this study was the knowledge about the occurrence and reasons behind shoulder injuries and muscle imbalances in adolescent Latvian freestyle swimmers.

Material and Methods: Thirty-six male competitive freestyle swimmers from 3 age groups (13-18 years old) from different clubs in Riga, Latvia, were selected. To find out the causes of shoulder injury and muscle imbalance, the data were collected using a questionnaire, a body posture assessment, and a video analysis. The data were analysed using the mean (M); standard deviations (SD or ±); chi-square test (χ^2); analysis of variance (ANOVA) and post-hoc Tukey's tests.

Results: The questionnaire showed significant relationships between using small and big paddles and experiencing pain, especially in group two. The body posture analysis for points of external ear opening, acromion, radial point, outer points of the palm, highest point of the Iliac crest, trochanter, and upper end of fibula bone showed significant differences ($p<0.05$). The body deviation forward, the so-called 'body falling' forward, was in groups. The video analysis revealed that the streamlined position is not achieved because the body is not in line.

Conclusions: The coaches should correctly evaluate the swimmers' technical errors. The present study's findings illustrate the need for a validated shoulder injury prevention program in swimming.

Keywords: body falling, prevention program, shoulder pain, video analysis

Innovative agonology (INNOAGON) – is an applied science dedicated to promotion, prevention, and therapy related to all dimensions of health and the optimization of activities that increase the ability to survive (from micro to macro scales) [57, 59].

Paddles – a type of plastic, flat cover for a swimmer's hand, used to increase the surface area covered water during training, there are two types, large and small [Wikipedia].

1. Introduction

Swimming is a popular recreational activity, but athletes' repetitive nature and intensive training increase interest in the frequency and degree of injuries during competitive seasons. Despite specializing in various strokes, swimmers mainly give their training volume to freestyle [1]. The repetitive freestyle stroke cycle can make swimmers vulnerable to musculoskeletal injuries in the upper extremity, knee, and spine [2]. Recent data from the FINA (Federation Internationale de Natation) World Championships indicate that overuse is the main cause of injuries (68.1%), with the shoulder being the most affected (26.3%), followed by the knee (10.1%), lower back (9.8%), and hip region (9.6%) [3]. Shoulder injuries occur among swimmers, with prevalence rates from 40% to 91% [4, 5]. Other studies maintain the need to recognize risk factors in different sports to understand the reasons behind injuries and recognize at-risk athletes [5]. Modifiable risk factors noticed in swimmers include asymmetries in rotator cuff muscle strength, difference in quadriceps and hamstring muscle strength, compromised scapular control, inadequate glenohumeral stability, abnormal posture, extreme ranges of hip, knee, and glenohumeral mobility, decrease in motor control, incorrect stroke technique/biomechanics, breathing, and intensive training volume [6, 7]. These modifiable risk factors are dynamically related to non-modifiable factors such as sex, age, stroke specialization, and years of training experience. In swimming, achieving the correct stroke pattern requires an appropriate body roll, thereby reducing the scapular protraction essential for maintaining optimal glenohumeral joint alignment. This adjustment decreases the support on muscles such as the serratus anterior and other scapular muscles [8]. A wider hand entry accompanies this correct body roll, reducing scapular upward rotation and humeral forward flexion. An early hand exit reduces humeral hyperextension and the extremes of internal rotation, avoiding potential impingement [9]. Overuse stands as the main cause of swimming injuries. Proficiency in swimming techniques reduces with increasing fatigue, causing muscles and joints to stress from repetitive movements [10, 11].

Increasing a small injury to a severe state is possible due to the intense volumes and intensities of swimming training. The primary shoulder pain can progress to shoulder instability accompanied by severe pain [9]. Pain and injury are higher in athletes with weak stroke techniques [12]. Richardson et al. [13] showed that shoulder pain affected 52% of elite and 27% of non-elite swimmers. In McMaster and Troup [14], shoulder pain was 47% (10-18 year-old swimmers), 66% (senior swimmers), and 73% (elite swimmers). The elite swimmers reported a higher pain frequency due to prolonged training durations and years of swimming experience. Yanai and Hay [15] reported that swimmers experience impingement in specific stroke cycles while avoiding it in others. Another study about South African swimmers underlined the high incidence of shoulder injuries in competitive swimmers, 71% (shoulder pain) and 64% (shoulder injuries) [16]. Among the pain complaints, 46% were related to the anterior shoulder, and 65% were related to overuse.

Establishing preventative ways for a swimmer's shoulder requires a comprehensive understanding of impairments, factors related to injury causation, and risk factors. Addressing impairments and reducing training mistakes related to overuse are the main points in preventing a swimmer's shoulder. This involves a deep understanding of swimming mechanics, training methodologies, and the stress on the shoulder during swimming. Despite the front crawl being the main stroke used by elite swimmers, even if not their preferred stroke [17], the lack of scientific research on injuries among Latvian swimmers is obvious. The status of shoulder injuries in Latvian freestyle swimmers remains unrevealed, impacting their international performance. Determining the prevalence of shoulder injuries in Latvian swimmers is the first step in guiding coaches' education and implementing measures to prevent shoulder injuries.

The aim of this study was the knowledge about the occurrence and reasons behind shoulder injuries and muscle imbalances in adolescent Latvian freestyle swimmers.

2. Materials and Methods

The decomposition of the above goal into research tasks determines two cognitive tasks: 1) assess the occurrence and reasons behind shoulder injuries and muscle imbalances through testing in 3 groups of adolescent Latvian freestyle swimmers, 2) compare the findings across three distinct groups; and the third application: offer recommendations to swimming coaches for avoiding and minimizing shoulder injuries, focusing on items that provide the risk of injuries.

Participants

The study included 36 male swimmers categorized into three age groups according to the standards of the swimming sport (Table 1). All swimmers had training durations from 4 to 9 years and a minimum of 330 World Aquatics (WA) points. The swimmers participated in Latvian Youth, Junior, and Open Championships. The criteria were participation in the Latvian Championships, no history of shoulder surgery, and no previous shoulder fractures.

Table 1. Characteristics of the experimental groups of swimmers (each, n = 12).

Group	Age (years)	Body height (cm)	Body mass (kg)	Swimming experience (years)	Training per week (sessions)
1	13 ±1.7	165.6 ±4.7	54.3 ±8.6	4.0 ±1.6	4.0 ±1.4
2	15.0 ±1.7	173.1 ±4.7	70.4 ±8.8	6.2 ±2.6	6.0 ±3.2
3	17.6 ±1.1	179.1 ±6.1	73.6 ±10.2	8.1 ±1.6	7.0 ±4.1

Parental consent was obtained through signed consent forms and the study protocol based on the ethical standards outlined in the Declaration of Helsinki, receiving approval from the Ethics Committee of the Latvian Academy of Sport Education.

Procedure

The questionnaire

The questionnaire, prepared by the author, contained the following information: age group according to the standards of the swimming sport, swimming experience, stroke, consent, permission, presence of injuries, and frequency of pain complaints associated with various swimming strokes and used equipment (Appendix).
The participants were informed to report any injuries in the past six months. This study defined a shoulder injury/problem as either pain or a diagnosed injury [18]. Consent from parents and assent from swimmers were obtained.

The body posture

It was measured through a diagnostic testing method which combined visual diagnostics methods from Vasilyeva [19] and muscular functional testing techniques from Kendall et al. [20] and Janda [21]. This diagnostic method requires the assessment of 8 sagittal points' changes from the vertical plane and functional testing of 7 muscle groups. Posture assessment was once before the training session, with the points marked on the athlete's body: external ear opening (EEO), acromion (Acr), radial point (RP), outer points of the palm (OPP), highest point of the iliac crest (HPI), trochanter (Tro), upper end of fibula bone (UEF), and outer ankle (OA). The participants were positioned in a relaxed stance near a vertical wall. The measurement involved determining the distance from the marked point to the vertical wall on the right and left sides with the meter stick. The middle distance from the ankle to the wall was calculated as 0.

Following Kendall's guidelines [20] for muscle functional testing, the central body and leg muscles contributing to posture were measured (Figure 1). The tests were conducted on seven muscle groups in a resting condition: blade fixators (BF), muscle rectus abdominis (MRA), and the postural muscles, such as muscle erector cervices (MEC), muscle pectoralis major upper part (PM), muscle iliopsoas (MI), muscle quadriceps femora's (MQF), hamstring muscles (HM). The functional condition of the postural muscles was as follows: 1. MEC: The chin must easily touch the chest. 2. PM: the shoulder must easily touch the table surface. 3. BF: the body moves forward, and the shoulder blades close to the back. 4. MRA: from the position lying on the table, the body moves slowly to the sitting position. 5. MI: the left leg must be bent free for 90 degrees. 6. MQF: the feet must be 10-15 cm from the buttock, passive movement. 7. HM: the straight leg must move easily to 90 degrees, which is passive movement.

Figure 1. Muscle functional testing.

Detect gross technical errors (underwater video)

During training, video analysis [1] used a camera (Go Pro Hero 5, GoPro, Inc., the United States) mounted on a sliding trolley along a track. This setup facilitated underwater and surface video recordings along the pool's long side, providing a lateral view of the swimmers' strokes. Additionally, two cameras (one underwater and one above water) were positioned at the end of the 25-meter pool to capture frontal views of each swimmer's freestyle biomechanics. All videos receive a precise examination by three swimming coaches with licenses of an LPF (Latvijas Peldēšanas Federācija; Swimming Federation of Latvia). This license qualifies coaches to train athletes of any category, be present at competitions, be Federal Technicians, and have at least ten years of experience in competitive swimming teams.
The evaluation was based on three indicators: stream (STR); straight pull (SP); hand entry (HD)>.

Statistical analysis

The analyses were conducted using Microsoft Office Excel and JASP version 0.17. Data are presented as frequency (N, n), the mean (M), standard deviations (SD or ±), minimum (min), maximum (max), degrees of freedom (df), significance level, and probability (p), Student's t-distribution (t), level of significance was set at $p < 0.05$.
The Q-Q Plots were used to assess the normality of the data, and no deviations were observed. The data were analysed using the Chi-square test, analysis of variance (ANOVA) [22], and post-hoc Tukey's tests [23]. The likelihood ratio test (LRT) [24] addresses assumptions of the Chi-squared test. The homogeneity of variance with Levene's test was confirmed by non-significant Levene's tests for all variables.

Ethical approval

This study was based on the guidelines of the Declaration of Helsinki. It was approved by the Ethical Committee of the Latvian Academy of Sport Education (LSPA, Protocol Nr. 1, Code Nr. 2).

3. Results

Questionnaire declarations

The greatest number of swimmers experienced pain during beginning of season (63.88%), fast interval exercise (61.11%),fast paddles (58.53%) and long distance (55.55%). Group 2 characterized itself higher percentage of pain (91.66%) during small paddles and big paddles exercises (training sessions), while the results of Group 1 (33.33% and 50%) and Group 3 (16.66% and 8.33%) was definitely lower (Table 2). The differences in proportions between feeling and not feeling pain in the Group 2 are statistically significant (p, .001), but insignificant in Groups 1 and 3 (Table 3).

Table 2. The phenomenon of pain sensation in swimmers from three twelve-person age groups during specificity of the training stimulus (sessions or exercises).

Specificity of the training stimulus	Declaration	Statistical data	Group			Total	
			1	2	3	number	%
small paddles	no pain	number	8	1	10	19	
		% within column	66.66	8.33	83.33		52.77
		standardized residuals	1.18	−3.77	2.59		
	pain	number	4	11	2	17	
		% within column	33.33	91.66	16.66		47.22
		standardized residuals	−1.180	3.77*	−2.59		
big paddles	no pain	number	6	1	11	18	
		% within column	50.00	8.33	91.66		50.00
		standardized residuals	0.0	−3.56	3.56		
	pain	number	6	11	1	18	
		% within column	50.0	91.66	8.33		50.00
		standardized residuals	0.00	3.53*	−3.56		
fast paddles	no pain	number	5	4	6	15	
		% within column	41.66	33.33	50.00		41.66
		standardized residuals	0.00	−0.71	0.71		

	pain	number	7	8	6	21	
		% within column	58.33	66.66	50.00		58.33
		standardized residuals	0.00	0.71	−0.71		
kickboard	no pain	number	9	10	10	29	
		% within column	75.00	83.33	83.33		80.55
		standardized residuals	−0.59	0.29	0.29		
	pain	number	3	2	2	7	
		% within column	25.00	16.66	16.66		19.44
		standardized residuals	0.59	−0.29	−0.29		
long distance	no pain	number	5	4	7	16	
		% within column	41.66	33.33	58.33		44.44
		standardized residuals	−0.23	−0.94	1.18		
	pain	number	7	8	5	20	
		% within column	58.33	66.66	41.66		55.55
		standardized residuals	0.23	0.94	−1.18		
resistance equipment	no pain	number	7	5	6	18	
		% within column	58.33	41.66	50.00		50.00
		standardized residuals	0.70	−0.7	0.00		
	pain	number	5	7	6	18	
		% within column	41.66	58.33	50.00		50.00
		standardized residuals	−0.70	0.70	0.00		
fast interval	no pain	number	6	4	4	14	
		% within column	50.00	33.33	33.33		38.88
		standardized residuals	0.96	−0.48	−0.48		
	pain	number	6	8	8	22	
		% within column	50.00	66.66	66.66		61.11
		standardized residuals	−0.96	0.48	0.48		
beginning of season	no pain	number	3	3	7	13	
		% within column	25.00	25.00	58.33		36.11
		standardized residuals	−0.98	−0.98	1.96		
	pain	number	9	9	5	23	
		% within column	75.00	75.00	41.66		63.88
		standardized residuals	0.98	0.98	−1.96		
total		number	12	12	12	36	
		% within column	100	100	100		100

Standardized residuals reflect the extent to which observed values deviate from expected values. Values above ±1.96 (or ±2.58 for stricter significance) indicate significant differences. We can conclude Group 2 consistently reports more pain than expected for both small and big paddles. Group 3 for big paddles reports less pain, suggesting a potential protective effect. Group 1 shows no significant differences, indicating the pain distribution is as expected (Table 3).

Small paddles

Group 1 (residuals: 1.18, −1.18): not significant (p>0.05), suggesting no significant difference between observed and expected pain/no pain (neutral). Group 2 (residuals: −3.77, 3.77): significant (p<0.001). The high positive residual (3.77) indicates more pain than expected, and the negative residual (−3.77) shows fewer pain-free athletes (bad). Group 3 (residuals: 2.59, −2.59): not significant (p>0.05). Although residuals suggest less pain than expected, the result is not statistically significant (neutral) (Table 3).

Big paddles

Group 1 (residuals: 0, 0): Not significant (p>0.05), showing no meaningful relationship between big paddles and pain (neutral). Group 2 (residuals: −3.56, 3.53): significant (p<0.001). The positive residual for pain (3.53) indicates more pain than expected, and the negative residual for no pain (−3.56) shows fewer pain-free athletes (bad). Group 3 (residuals: 3.56, −3.56): not significant (p>0.05). The high positive residual for no pain (3.56) indicates less pain than expected (good) (Table 3).

Table 3. The phenomenon of pain sensation in swimmers from three twelve-person age groups in two different circumstances of specialized training with paddles.

Specificity of the training stimulus	Group	Health effect				Statistical indicators		
		no pain		pain		standardized residuals		p-value
		number	%	number	%			
small paddles	1	8	66.6	4	33.3	1.18	−1.18	>0.05
	2	1	8.33	11	91.6	−3.77	3.77	**<0.001**
	3	10	83.3	2	16.6	2.59	−2.59	>0.05
big paddles	1	6	50	6	50	0	0	>0.05
	2	1	8.3	11	91.6	−3.56	3.53	**<0.001**
	3	11	91.6	1	8/3	3.56	−3.56	>0.05

The results of the Chi-squared test and the LRT (Table 4) showed a significant relationship between small paddles and pain (χ^2 (2, N = 36) = 14.93, LRT (2, N = 36) = 16.82). In contrast, the results of groups one and three showed no pain (66.6% and 83.3%). A significant relationship was found in big paddles using and feeling of pain (χ^2 (2, N = 36) = 16.66, LRT (2, N = 36) = 19.50. The Chi-square and LRT showed no significant relationship for the following experimental variables: fast paddles, kickboard, long distance, resistance equipment, fast interval, the beginning of the season, and the feeling of pain (p>0.05).

Table 4. The phenomenon of pain sensation by swimmers (n = 36) during different methods of training stimulation verified by the indicators of Chi-squared (χ^2) and the likelihood ratio test (LRT).

Specificity of the training stimulus	Test	Indicator	p-value
small paddles	χ^2	14.93	**<0.001**
	LRT	16.82	**<0.001**
big paddles	χ^2	16.66	**<0.001**
	LRT	19.50	**<0.001**
fast paddles	χ^2	0.68	0.71
	LRT	0.68	0.70
kickboard	χ^2	0.35	0.83
	LRT	0.34	0.84
long distance	χ^2	1.57	0.45
	LRT	1.58	0.45
resistance equipment	χ^2	0.66	0.71
	LRT	0.67	0.71
fast interval	χ^2	0.93	0.62
	LRT	0.92	0.62
beginning of season	χ^2	3.85	0.14
	LRT	3.79	0.14

The body posture

For OPP, a significant difference was found F(2, 33) = 145.4, p<0.001. Group 1 was significant (M = 6.96, ±0.21) compared to Groups 3 and 2. HPI results showed a considerable difference F(2, 33) = 41.23, p<0.001. Group 1 was significantly higher (M = 7.91, ±0.15) than Group 2 and smaller than Group 3. Significant differences were found in EEO scores (F (2, 33) = 69.3, p<0.00). Post hoc Tukey's tests showed swimmers in Group 1 with higher (M = 10.92, ±0.18) than Group 3 but lower than Group 2. RP results showed a significant difference (F (2, 33) = 41.0, p<0.001). Swimmers in Group 1 had significantly lower results (M = 2.63, ±0.21) than those of Group 3 and Group 2 Acr scores were significant F (2, 33) = 53.0, p<0.001. Post hoc Tukey's tests showed that Group 1 had lower (M = 10.72, ±0.15). Tro's result was significant: F(2, 33) = 43.52, p<0.001. Athletes in Group 1 had a significantly higher mean (M = 5.94, ±0.17) than Group 3 and substantially lower than Group 2. UEF scores significantly differed: F(2, 33) = 5.49, p = 0.001. Athletes in Group 1 had a significantly higher mean (M = 1.98, ±0.17) than those in Group 3 (Table 5 and 6, also Figure 3).

Table 5. ANOVA results for body posture indicators of swimmers (n = 36) – order variable from the highest SS value.

Point marked on the body	SS	df	MS	F	p
outer points of the palm OPP	11.7	2 (33)	5.88	145.4	<0.05
highest point of the iliac crest HPI	4.60		2.30	41.23	
external ear opening EEO	4.09		2.04	69.3	
radial point RP	3.93		1.96	41.0	
acromion Acr	2.60		1.30	53.0	
trochanter Tro	2.38		1.19	43.52	
upper end of fibula bone UEF	0.29		0.14	5.49	

SS sum of squares; **df** degrees of freedom; **MS** mean square; **F** distribution; **p** significance level

Table 6. Results for body posture of swimmers (n = 36) based on ANOVA and follow up post hoc analysis indicators – order variable from the highest SS value between Group 1 and Group 3.

Point marked on the body	Cas	ANOVA					Comp.	Post hoc (Tukey HSD)			
		SS	df	MS	F	p		Diff	SE	t	p Tukey
outer points of the palm OPP	G	11.7	2	5.88	145.4	**0.001**	1–3	1.40	0.08	17.0	**0.001**
	R	1.33	33	0.04			1–2	0.74	0.08	9.0	**0.001**
							3–2	−0.65	0.08	−8.0	**0.001**
highest point of the iliac crest HPI	G	4.60	2	2.30	41.23	**0.001**	1–3	−0.40	0.09	−4.1	**0.001**
	R	1.84	33	0.05			1–2	0.47	0.09	4.9	**0.001**
							3–2	0.87	0.09	9.0	**0.001**
external ear opening EEO	G	4.09	2	2.04	69.3	**0.001**	1–3	0.30	0.07	4.2	**0.001**
	R	0.97	33	0.03			1–2	−0.51	0.07	−7.3	**0.001**
							3–2	−0.81	0.07	−11.6	**0.001**
radial point RP	G	3.93	2	1.96	41.0	**0.001**	1-3	−0.50	0.08	−5.6	**0.001**
	R	1.58	33	0.04			1–2	−0.80	0.08	−8.9	**0.001**
							3–2	−0.29	0.08	−3.2	**0.007**
acromion Acr	G	2.60	2	1.30	53.0	**0.001**	1–3	−0.47	0.06	−7.4	**0.001**
	R	0.81	33	0.02			1-2	−0.63	0.06	−9.8	**0.001**
							3-2	−0.15	0.06	−2.4	**0.04**
trochanter Tro	G	2.38	2	1.19	43.52	**0.001**	1–3	0.53	0.06	7.8	**0.001**
	R	0.90	33	0.02			1–2	−0.02	0.06	−0.3	0.92
							3–2	−0.55	0.06	−8.2	**0.001**
upper end of fibula bone UEF	G	0.29	2	0.14	5.49	**0.001**	1–3	0.19	0.06	2.8	**0.01**
	R	0.88	33	0.02			1–2	0.19	0.06	2.8	**0.01**
							3–2	0.19	0.06	2.8	**0.01**

G group; **R** residuals; **df** degrees of freedom; **SS** sum of squares; **MS** mean square; **F** distribution; **Diff** difference; **SE** standard error; **t** Student's t-distribution

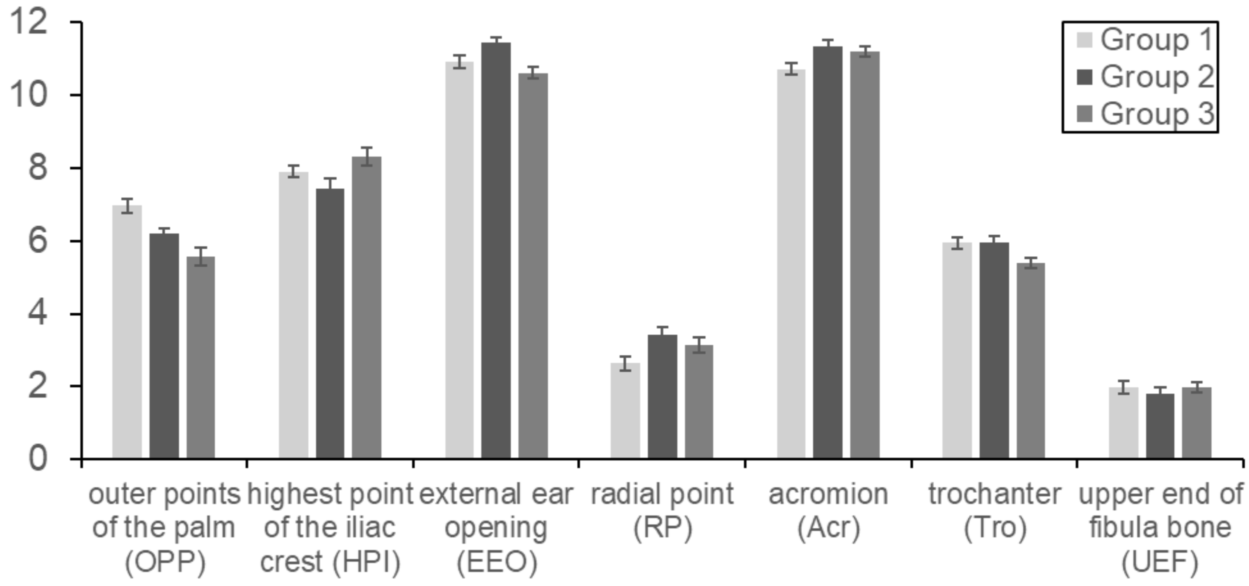

Figure 3. Descriptive statistics of body posture for swimmers (n = 36).

Muscle functional

Significant differences in PM were found between the groups $F(2, 33) = 24.8$, $p<0.001$. Group 1 (M = 66.58, ±3.57) had a lower mean than Group 3, with no significant difference between Group 1 and Group 2 ($p = 0.87$). Significant differences were in MEC measurements $F(2, 33) = 16.2$, $p<0.00$. The athletes in Group 1 (M = 50.91, ±3.17) had a lower mean than Group 3 and Group 2. HM significantly differed between the Groups ($F(2, 33) = 4.2$, $p = 0.023$). Group 1 (M = 54.91, ±2.99) had a lower mean than Group 2, with no significant differences between Group 3 ($p = 0.45$). Significant differences in BF measurements were observed between the Groups $F(2, 33) = 6.1$, $p = 0.006$. Group 1 mean (M = 61.25, ±3.44) was lower than Group 3 and Group 2. Significant differences in MRA were observed among the Groups $F(2, 33) = 7.0$, $p = 0.007$. Group 1 (M = 55.66, ±2.64) had a lower mean than Group 3 and Group 2. No significant difference was found between Groups 2 and 3 ($p = 0.38$). Significant differences in MI were found between the Groups ($F(2, 33) = 4.2$, $p = 0.02$). Group 1 (M = 64.08, ±1.62) had a lower mean than Group 2, with no significant differences between Group 1 and Group 3 ($p = 0.54$) and between Group 2 and Group 3 ($p = 0.17$). No significant difference was found between groups 2 and 3 ($p = 0.30$). No significant differences were found in MQF between the groups $F(2, 33) = 0.4$, $p = 0.65$ (Table (Table 7 and 8, also Figure 3).).

Table 7. ANOVA results for muscle points of swimmers (n = 36) – order variable from the highest SS value.

Muscle	**SS**	**df**	**MS**	**F**	***p***
muscle pectoralis major upper part PM	525.3	2(33)	262.6	24.8	**<0.05**
muscle erector cervices MEC	230.7		115.3	16.2	
hamstring muscles HM	105		52.5	4.2	
blade fixators BF	101.7		50.8	6.1	
muscle rectus abdominis MRA	63.7		31.8	7.0	
muscle iliopsoas MI	38.3		19.1	4.2	
muscle quadriceps femora's MQF	8.16		4.08	0.4	>0.05

SS sum of squares; **MS** mean square; **F** distribution

Table 8. Results for body posture of swimmers (n = 36) based on ANOVA and follow up post hoc analysis indicators.

Point marked on the body	**Case**	**ANOVA**					**Comparisons**	**Post hoc (Tukey HSD)**			
		SS	**df**	**MS**	**F**	**p**		**Diff**	**SE**	**t**	**p Tukey**
muscle pectoralis major upper part PM	G	525.3	2	262.6	24.8	**0.001**	1–3	−7.75	1.32	−5.8	**0.001**
							1–2	0.66	1.32	0.5	0.87
	R	348.5	33	10.5			3–2	8.41	1.32	6.3	**0.001**
muscle erector cervices MEC	G	230.7	2	115.3	16.2	**0.001**	1–3	−4.08	1.08	−3.7	**0.002**
	R	234.9	33	7.1			1–2	−6.08	1.08	−5.5	**0.001**
							3–2	−2.00	1.08	−1.8	0.17
hamstring muscles HM	G	105	2	52.5	4.2	**0.023**	1–3	−2.41	1.44	−1.6	0.22
	R	410	33	12.4			1–2	−4.16	1.44	−2.8	**0.018**
							3–2	−1.75	1.44	−1.2	0.45
blade fixators BF	G	101.7	2	50.8	6.1	**0.006**	1-3	−4.08	1.17	−3.4	**0.004**
							1–2	−2.5	1.17	−2.1	0.10
	R	275.1	33	8.3			3–2	1.58	1.17	1.3	0.38
muscle rectus abdominis MRA	G	63.7	2	31.8	7.0	**0.007**	1–3	−3.25	0.95	−3.4	**0.005**
	R	178.5	33	5.4			1-2	−1.83	0.95	−1.9	0.14
							3-2	1.41	0.95	1.4	0.30
muscle iliopsoas MI	G	38.3	2	19.1	4.2	**0.02**	1–3	−0.91	0.87	−1.0	0.54
	R	149.8	33	4.5			1–2	−2.5	0.87	−2.8	**0.019**
							3–2	−1.5	0.87	−1.8	0.17
muscle quadriceps femora's MQF	G	8.16	2	4.08	0.4	0.65					
	R	318.5	33	9.65							

G group; **R** residuals; **df** degrees of freedom; **SS** sum of squares; **MS** mean square; **F** distribution; **Diff** difference; **SE** standard error; **t** Student's t-distribution

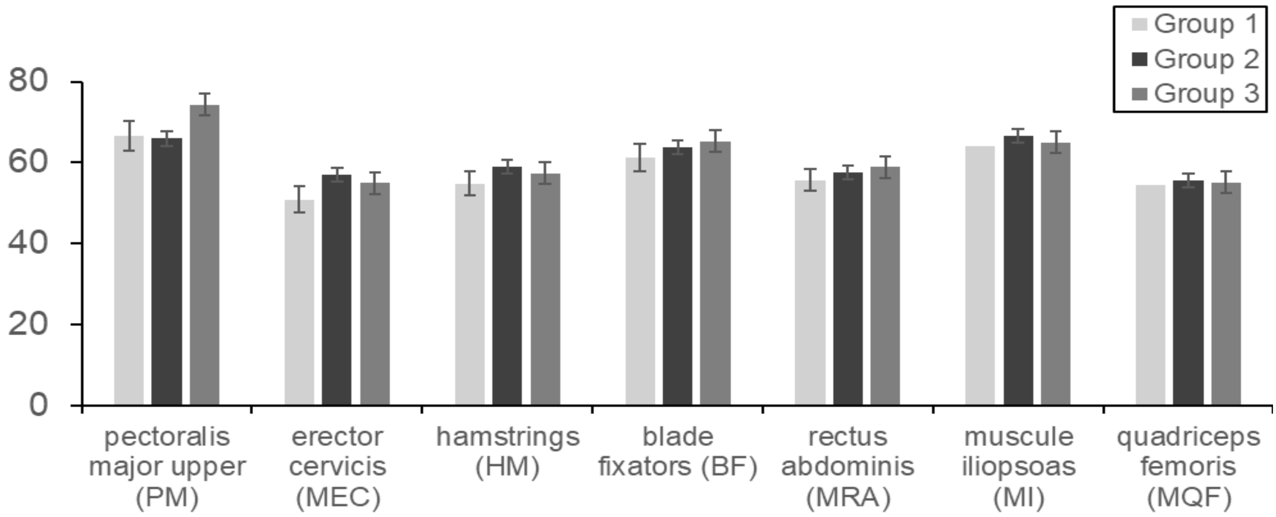

Figure 3. Descriptive statistics of muscle functional testing for swimmers (n = 36).

Significant differences were found in stream measurements F(2, 33) = 10.8, p<0.001. Group 1 (M = 63.25 ±3.33) had a higher mean than Group 3 and Group 2. Significant differences were observed in straight pull measurements F (2, 33) = 11.6, p<0.001). Group 1 (M = 62.16, ±3.71) had a lower mean than Group 3 and a higher mean than Group 2. No significant differences were found in hand entry measurements F (2, 33) = 0.01, p = 0.98 (Table 9 and 10, also Figure 4).

Table 9. ANOVA results for underwater video observation (technical errors) of swimmers (n = 36).

Technical error	SS	df	MS	F	*p*
stream STR	276.5		138.2	10.8	**<0.05**
straight pull SP	228.2	2(33)	114.1	11.6	
hand entry HD	0.38		0.19	0.01	>0.05

Table 10. Results for underwater video observation (technical errors) of swimmers (n = 36) based on ANOVA and follow up post hoc analysis indicators.

Point marked on the body	Case	ANOVA					Comparisons group	Post hoc (Tukey HSD)			
		SS	df	MS	F	p		Diff	SE	t	p Tukey
stream STR	G	276.5	2	138.2	10.8	**0.001**	1–3	6.0	1.45	4.1	**0.001**
	R	419.5	33	12.7			1–2	5.7	1.45	3.9	**0.001**
							3–2	−0.2	1.45	−0.1	0.98
straight pull SP	G	228.2	2	114.1	11.6	**0.001**	1–3	−3.16	1.27	−2.4	**0.04**
	R	322.0	33	9.7			1–2	3.0	1.27	2.3	0.06
							3–2	6.1	1.27	4.8	**0.001**
hand entry HD	G	0.38	2	0.19	0.01	0.98					
	R	427.2	33	12.9							

G group; **R** residuals; **df** degrees of freedom; **SS** sum of squares; **MS** mean square; **F** distribution; **Diff** difference; **SE** standard error; **t** Student's t-distribution

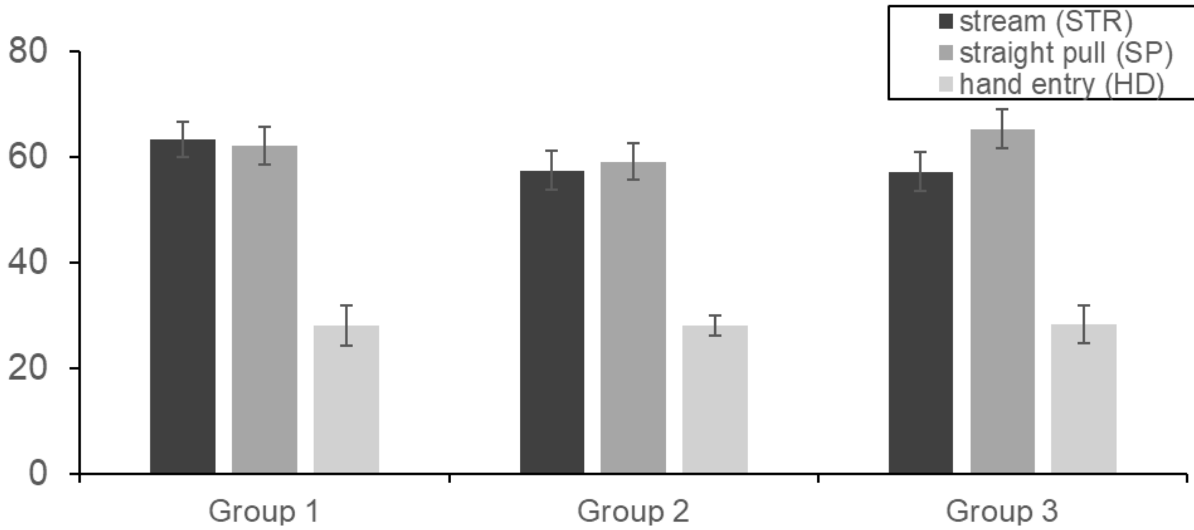

Figure 4. Descriptive statistics for technical errors of swimmers (n = 36).

4. Discussion

A higher frequency of pain complaints was observed in age group 2 (15-16 years old) while swimming. This finding aligns with the understanding that adolescents may be more susceptible to injuries during rapid growth. A cross-sectional survey [16] on competitive South African swimmers aged 13-25 also reported a high incidence of shoulder pain (71%) and actual shoulder injuries (64%), including impingement, bursitis, and muscle strain.

Baxter et al. [25] research indicated that this imbalance stems from a lack of harmony between core stabilizer strength, scapular stabilizers, and rotator cuff muscles. Collectively, these components contribute to stabilizing the glenohumeral joint during rapid mobility [26]. The study focused on freestyle swimmers who engaged in repetitive overhead actions, swimming 6-9 sessions per week. This observation aligns with prior research [13, 2], highlighting that 75% of shoulder injuries occurred in freestyle swimmers. In contrast to our findings, two cross-sectional studies [27, 28] did not show a significant correlation between swimmers' age and shoulder pain. Kruger et al. [24] study involved swimmers with an average age of 50, whereas our study focused on swimmers under 18. Tate et al. [28], using age groups (8-77 years), identified differences in exposure and physical characteristics between participants with and without shoulder pain, disability, and dissatisfaction but found no age-related distinctions.

Werner et al. [29] determined that non-traumatic shoulder tendonitis is uncommon before age 40 but becomes relatively prevalent in older individuals. This connection is primarily linked to cumulative injuries over time and the body's reduced capacity for swift injury repair. Age-related degenerative changes in the component of connective tissue surrounding joints contribute to increased range of motion (ROM) and joint stiffness [30], leading to a rise in shoulder injuries with age. In contrast, a study [31] found no correlation between stroke specialty and shoulder pain in swimmers, attributing the injuries to the high volume of swimming training.

Competitive level correlates with shoulder pain, as competitive swimmers undergo professional training programs and sport-specific conditioning to enhance performance. This study focused on Latvian swimmers participating in various competitions. Our findings align with [32], highlighting that competitive swimmers exhibit significantly higher shoulder pain than recreational swimmers.

In our study, the use of both small and large paddles resulted in the highest number of pain complaints across age groups, consistent with findings from a study [9] indicating that hand paddles and pulling sets are discouraged due to the excessive stress they place on the shoulder, potentially irritating injuries. A kickboard with flexed elbows was suggested to prevent shoulder impingement, though modification might be necessary to prevent forward shoulder elevation. In contrast, Tate et al. [28] found no association between hand paddles and shoulder pain or injury. We observed changes in posture (forward falling of the body in the shoulder area) and functional muscle alterations across groups. Muscle testing results revealed changes in postural muscles within groups of swimmers. In line with Janda's perspective, muscles undergoing shortening can become tight, leading to an elongated and weakened position in opposing muscles [33]. This imbalance pattern is linked to the forward head, rounded-shoulder posture, and midthoracic spinal kyphosis and aligns with our previous study [34]. The main movements in freestyle swimming, specifically shoulder adduction and internal rotation [35], contribute to excessive shoulder internal rotation and adduction strength [35], influencing swimmers' postural features. Given the repetitive shoulder rotation movements in freestyle swimming, young competitive swimmers are sensitive to developing unfavourable upper quarter postural features, potentially resulting in soft tissue injuries and shoulder pain [36]. Various factors, including shoulder rotation movements and inadequate recovery from intense training sessions, expose swimmers to muscle length-tension changes and modifications in the thoracic spine and shoulder complex [37]. With an average swimmer performing over 1 million strokes per year with each arm [38], it is anticipated that athletes specializing in freestyle from an early age may face an increased risk of developing postural imbalances as they transition into adulthood [39].

Additionally, extended study hours, outdoor training, backpack usage, and school desk ergonomics affect adolescents' performance and physical characteristics [40-44]. According to recommendations [45], addressing this positional or postural fault resulting from muscle imbalance involves stretching tight muscles and strengthening antagonistic muscles. A stretching and strengthening program targeting shoulder posture may reduce the risk of shoulder injury. In the context of the video analysis focusing on the front crawl stroke (freestyle), the study's findings showed challenges in achieving the proper streamlined position due to posture changes. The body lacks alignment, causing stretching of the muscles supporting the shoulder joint and upward movement of the blade. This altered posture increases the load on the shoulder joint, particularly when executing a straight pull that crosses the body's midline. Maintaining a streamlined position is a fundamental aspect of all swimming strokes. It is characterized by a streamlined body posture with both arms elevated to ensure a horizontal, straight position and reduce resistance underwater [46]. This study defines the streamlined position as the body posture during maximal horizontal gliding in water, aiming to optimize swimming performance. Previous research [47] has highlighted the positive impact of the streamlined position in reducing passive drag and enhancing overall swimming performance.

While maintaining a streamlined position is acknowledged across all strokes, a different study [2] reported that achieving this position involves hyperextension of the lower back. Surprisingly, our findings are consistent with the study [48], which noted a significant difference in inducing lumbar extension to maintain the streamlined position in collegiate male competitive swimmers. This suggests that evaluating and improving lumbar alignment during the streamlined position is crucial, even for skilled swimmers. The front crawl, breaststroke, and butterfly strokes carry the risk of incorrect stroke mechanics, particularly concerning catch positions and force application above shoulder height [46]. Many swimmers modify their strokes to reduce discomfort, leading to potential deviations from optimal movement patterns. During the early pull-through phase, a typical hand entry occurs close to the midline, with the elbow positioned above the water's surface. However, individuals with shoulder pain may adjust their technique by entering the hand further from the midline, accompanied by a lower elbow closer to the water's surface. This modification helps prevent impingement, characterized by total elevation with internal rotation and horizontal adduction. Another adaptation occurs after the pull-through phase when, ideally, the hand should be near the thigh with internal shoulder rotation. Swimmers experiencing shoulder pain tend to externally rotate the shoulder, shortening the pull-through phase to avoid impingement. These adjustments are made to accommodate the discomfort associated with specific movement patterns.

Recommendations for swimming coaches

The study's findings highlight the prevalence of shoulder pain among young swimmers. Coaches play a crucial role in assessing technical errors, as addressing these errors can lead to improved performance and serve as a vital preventive measure against shoulder injuries. An optimal front crawl stroke involves a body roll of approximately 45° along the longitudinal axis [1], contributing to a reduced risk of shoulder impingement during recovery. The anthropomorphic changes accompanying puberty may elevate the likelihood of shoulder issues, which could be influenced by rapid developmental changes altering stroke techniques. Emphasizing the importance of an effective front crawl stroke, particularly in these age groups, is crucial. Muscle evaluation is essential for a comprehensive examination, which coaches, athletic trainers, or physiotherapists may undertake to reduce injury risks. Conducting precise biomechanical studies in higher-level clubs or with more competitive individual swimmers is recommended. Adjustments to the swimming training load should address changes in upper-quarter postural alignment. Pre-rehabilitative measures should be incorporated into the training regimen, including corrective exercises targeting the strengthening of the shoulder girdle and thoracic spine muscles. To maintain the desired freestyle technique, it is advisable to combine stretching, warm-up routines targeting specific muscle groups for optimal movement patterns, and careful monitoring during training sessions.

Additionally, coaches, along with individuals in secondary schools or clubs, should be mindful of the sensitivity of competitive adolescent swimmers to functional postural imbalances. Experts who deal with supplementary and at the same time general development training for all sports disciplines, and especially in swimming, reducing the effects of specialist sports training are personal trainers []. It is recommended that posture education and whole-body conditioning be included in periodization plans. Video analysis of the stroke can analyse even minimal defects in swimming technique, offering an opportunity for correction to enhance performance and prevent specific forms of pain, such as shoulder pain.

Certain limitations must be acknowledged in this study. Future research examining postural changes over a macrocycle, interventions, or considering impairment levels could enhance the comprehension of postural imbalances in competitive adolescent freestyle swimmers. Another limitation is focusing on a specific gender and a single swimming stroke. Assessing postural angles for both males and females would provide insights into the postural characteristics of this population. While the freestyle swimming stroke is important, exploring postural changes with other swimming strokes (butterfly, backstroke, and breaststroke) could contribute to a more comprehensive understanding of postural alignment in swimmers.

Future studies should also consider the impact of devices such as smartphones on upper body posture. Additionally, various variables, including shoulder rotation range, frequency of dryland sessions, training intensity, competition, core stability, and growth, may have influenced the development of shoulder pain in these swimmers. It is important to note that the questionnaire used was not tested for reliability and relied on swimmers' self-reporting accuracy. Despite defining shoulder pain in the questionnaire, the self-reported nature of pain may have influenced the results. Under-reporting a history of pain and subsequent shoulder pain is possible, as many swimmers may perceive mild to moderate pain as normal and something to be tolerated.

Health implications

The results of these studies provide important evidence that uncritical transfer of methods, means, and training aids (swimming paddles) to recreational, preventive, and rehabilitation swimming would be highly counterproductive. Half a century ago, swimming (on the border of professional) was recommended along with wrestling (precisely because of health aspects) as the most valuable 'sports of life' [51-54]. We see a certain analogy of mental barriers with a seemingly distant phenomenon – the inevitable, unintentional fall of every person [55]. Lack of swimming skills in certain circumstances is an obvious threat to life, as is a fall in a much wider class of often difficult to predict events. Both of the signalled phenomena are the subject of research by the new applied science INNOAGON, closely related to preventive medicine [56-62].

5. Conclusions

Preventing shoulder injuries in swimmers requires thorough preseason screening to identify potential impairments and training errors that might lead to symptoms. Future research should explore whether addressing specific impairments before the season can effectively reduce the incidence of a swimmer's shoulder and determine the most significant risk factors. Investigating shoulder pain in conjunction with other modifiable and non-modifiable factors will enhance the comprehension of risk factors for shoulder injuries in swimmers, guiding the development of injury prevention programs. There is a lack of sufficient validation for shoulder injury prevention programs in the scientific literature. The coaches should correctly evaluate the swimmers' technical errors. The present study's findings illustrate the need for a validated shoulder injury prevention program in swimming.

Data Availability Statement: The data supporting this study's findings are available from the corresponding author upon reasonable request.

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References

1. Virag B, Hibberd EE, Oyama S et al. Prevalence of freestyle biomechanical errors in elite competitive swimmers. Sports Health 2014; 6(3): 218-224
2. Wanivenhaus F, Fox AJ, Chaudhury S et al. Epidemiology of injuries and prevention strategies in competitive swimmers. Sports Health 2012; 4(3): 246-251
3. Prien A, Mountjoy M, Miller J et al. Injury and illness in aquatic sport: how high is the risk? A comparison of results from three FINA World Championships. British Journal of Sports Medicine 2017; 51(4): 277-282
4. Martins LCX, Paiva JR, Freitas AC et al. Prevalence of pain and associated factors in elite swimmers. Science & Sports 2014; 29(3): e11-e14
5. Tessaro M, Granzotto G, Poser A et al. Shoulder pain in competitive teenage swimmers and it's prevention: a retrospective epidemiological cross sectional study of prevalence. International Journal of Sports Physical Therapy 2017; 12(5): 798-811
6. Hibberd EE, Myers JB. Practice habits and attitudes and behaviours concerning shoulder pain in high school competitive club swimmers. Clinical Journal of Sport Medicine 2013; 23(6): 450-455
7. Jakubovskis G, Zuša A, Solovjova J et al. Effects of breathing exercises on young swimmers' respiratory system parameters and performance. MCB Molecular and Cellular Biomechanics 2024; 21(1): 1-13
8. Batalha NM, Raimundo AM, Tomas-Carus P et al. Shoulder rotator cuff balance, strength, and endurance in young swimmers during a competitive season. Journal of Strength and Conditioning Research 2013; 27(9): 2562-2568
9. McMaster WC, Roberts A, Stoddard T. A correlation between shoulder laxity and interfering pain in competitive swimmers. The American Journal of Sports Medicine 1998; 26 (1): 83-86
10. Pink MM, Tibone JE. The painful shoulder in the swimming athlete. The Orthopedic Clinics of North America 2000; 31(2): 247-261
11. Schlueter KR, Pintar JA, Wayman KJ et al. Clinical Evaluation Techniques for Injury Risk Assessment in Elite Swimmers: A Systematic Review. Sports Health 2021; 13(1): 57-64
12. Chorley J, Eccles RE, Scurfield A. Care of Shoulder Pain in the Overhead Athlete. Pediatric Annals 2017; 46(3): 112-113
13. Richardson AB, Jobe FW, Collins HR. The shoulder in competitive swimming. The American Journal of Sports Medicine 1980; 8(3): 159-163
14. McMaster WC, Troup J. A survey of interfering shoulder pain in United States competitive swimmers. The American Journal of Sports Medicine 1993; 21(1): 67-70
15. Yanai T, Hay JG. Shoulder impingement in front-crawl swimming: II. Analysis of stroking technique. Medicine & Science in Sports & Exercise 2000; 32(1): 30-40
16. Puckree T, Thomas KJ. Shoulder injuries in competitive swimmers in KwaZulu. South African Journal of Sports Medicine 2006; 18(1): 10-12
17. Walker H, Gabbe B, Wajswelner H et al. Shoulder pain in swimmers: a 12-month prospective cohort study of incidence and risk factors. Physical Therapy in Sport 2012; 13(4): 243-249
18. Ostrander T, DeGraauw C, Howarth SJ et al. Prevalence of shoulder problems in youth swimmers in Ontario. The Journal of the Canadian Chiropractic Association 2022; 66(3): 244-252
19. Vasilyeva LF. Visual diagnosis of disorders of the statics and dynamics of the human musculoskeletal system. Ivanovo 1996. Russian
20. Kendall FP, McCreary EK, Provance PG. Muscle Testing and Function. Lippincott. Williams and Wilkins, Philadelphia 1993

21. Janda V. Manuelle muskelfunktion diagnostic. Berlin Ullstein 1994; German
22. "ANOVA Design". bluebox.creighton.edu. Retrieved 23 January 2023
23. Pickles A. An Introduction to Likelihood Analysis. Norwich: W. H. Hutchins & Sons, 1985: 24-27
24. Levene H. In Contributions to Probability and Statistic: Esseys in Honor of Harold Hotelling, I. Olkin et al eds., Stanford University Press 1960" 278-292
25. Baxter-Jones A, Maffulli N, Helms P. Low injury rates in elite athletes. Archives of Disease in Childhood 1993; 68(1): 130-132
26. Johnson JN, Gauvin J, Fredericson M. Swimming biomechanics and injury prevention: new stroke techniques and medical considerations. The Physician and Sportsmedicine 2003; 31(1): 41-46
27. Kruger PE, Dressler A, Botha M. Incidence of shoulder injuries and related risk factors among master swimmers in South Africa. African Journal for Physical Health Education, Recreation and Dance 2012; 18(1): 57-76
28. Tate A, Turner GN, Knab SE et al. Risk factors associated with shoulder pain and disability across the lifespan of competitive swimmers. Journal of Athletic Training 2012; 47(2): 149-158
29. Werner RA, Franzblau A, Gell N et al. A longitudinal study of industrial and clerical workers: predictors of upper extremity tendonitis. Journal of Occupational Rehabilitation 2005; 15(1): 37-46
30. Baechle TR, Earle RW. (Eds.). Essentials of strength training and conditioning. Human Kinetics 2008
31. Wymore L, Reeve RE, Chaput CD. No correlation between stroke specialty and rate of shoulder pain in NCAA men swimmers. International Journal of Shoulder Surgery 2012; 6(3): 71-75
32. Sein ML, Walton J, Linklater J et al. Shoulder pain in elite swimmers: primarily due to swim-volume-induced supraspinatus tendinopathy. British Journal of Sports Medicine 2010; 44(2): 105-113
33. Page P. Shoulder muscle imbalance and subacromial impingement syndrome in overhead athletes. International Journal of Sports Physical Therapy 2011; 6(1): 51-58
34. Solovjova J, Boobani B, Grants J et al. Effect of different sports on young athlete's posture swimmers and cyclists. Arch Budo Sci Martial Arts Extreme Sports 2023; 19: 141-149
35. Matthews MJ, Green D, Matthews H et al. The effects of swimming fatigue on shoulder strength, range of motion, joint control, and performance in swimmers. Physical Therapy in Sport 2017; 23; 118-122
36. Liaghat B, Juul-Kristensen B, Frydendal T et al. Competitive swimmers with hypermobility have strength and fatigue deficits in shoulder medial rotation. Journal of Electromyography and Kinesiology 2018; 39: 1-7
37. Meeuwisse WH, Tyreman H, Hagel B et al. A dynamic model of etiology in sport injury: the recursive nature of risk and causation. Clinical Journal of Sport Medicine 2007; 17(3): 215-219
38. Kluemper M, Uhl T, Hazelrigg H. Effect of stretching and strengthening shoulder muscles on forward shoulder posture in competitive swimmers. Journal of Sport Rehabilitation 2006; 15(1): 58
39. Atalar H, Yilmaz C, Polat O et al. Restricted scapular mobility during arm abduction: implications for impingement syndrome. Acta Orthopaedica Belgica 2009; 75(1): 19-24
40. Boobani B, Grants J, Litwiniuk A et al. Effect of Walking in Nature on Stress Levels and Performance of Taekwondo Athletes in the Competition Period. Journal of Kinesiology and Exercise Sciences 2024; 34 (106): 113-121
41. Hibberd EE, Laudner K, Berkoff DJ et al. Comparison of Upper Extremity Physical Characteristics Between Adolescent Competitive Swimmers and Nonoverhead Athletes. Journal of Athletic Training 2016; 51(1): 65-69
42. Boobani B, Grants J, Boge I et al. Effect of outdoor recreation activity on mental toughness of taekwondo athletes in competition period. Arch Budo Sci Martial Art Extreme Sport 2023; 19: 113-121
43. Ruivo RM, Pezarat-Correia P, Carita AI. Cervical and shoulder postural assessment of adolescents between 15 and 17 years old and association with upper quadrant pain. Brazilian Journal of Physical Therapy 2014; 18(4); 364-371
44. Boobani B, Grants J, Glaskova-Kuzmina T et al. Effect of green exercise on stress level, mental toughness, and performance of taekwondo athletes. Arch Budo J Inn Agon 2024, 20: 29-40
45. Sahrmann S. Diagnosis and Treatment of Movement Impairment Syndromes-E-Book Elsevier Health Sciences; 2001
46. Maglischo EW. Swimming fastest. Human Kinetics; 2003
47. Elliott B. Body Form Influences on the Drag Experienced by Junior Swimmers. International Research in Sports Biomechanics 2002; 310-317

48. Kobayashi K, Kaneoka K, Takagi H et al. Lumbar alignment and trunk muscle activity during the underwater streamline position in collegiate swimmers. J. Swim. Res 2015; 23(1): 33-43
49. Litwiniuk A, Grants J, Waldzinski T. Professional competences of personal trainers. Arch Budo Sci Martial Art Extreme Sport 2020; 16: 79-84
50. Kruszewski A, Litwiniuk A. The importance of the quality of education of personal trainers from the perspective of personal security. Arch Budo Sci Martial Arts Extreme Sports 2021; 17: 197-202
51. Enciclopedia Completea de Ejercicios. Madrit: EDAF; 1980. Spanish
52. Barczyński BJ, Graczyński MR, Kalina RM. Budo – a unique keyword of life sciences. Arch Budo 2009; 5: 17-19
53. Kruszewski A. Wrestling fight-between tradition, sport and spectacle. Arch Budo 2023; 19: 21-27
54. Kruszewski A. Antique wrestling is the prototype of a relatively gentle and honourable self-defence. Arch Budo Sci Martial Art Extreme Sport 2023; 19: 5-10
55. Gąsienica Walczak B, Kalina A, Litwiniuk A et al. Mental barriers to reduce vulnerability to injury during a fall: an elementary issue of personal safety in a global civilization. Health Problems of Civilization. 2024; 18(4): 453-662
56. Kalina RM. Agonology – the prospect of an effective defence of peace and unrestricted freedom of scientists. Arch Budo 2016; 12: 1-13
57. Kalina RM. Innovative Agonology – Its Definition, Detailed Theories, General Rule of Struggle, and Laws. Proceedings of the 14th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences (AHFE 2023); 2023 Jul 20-24; San Francisco, USA. Healthcare and Medical Devices 2023; 79: 272-279
58. Kalina RM. Methodology of complementary research as the basis for integrating science in fulfilling its social mission in the future. Arch Budo 2023; 19: 77-82
59. Kalina RM, Kruszewski A. INNOAGON is an acronym for 'innovative agonology', but is not synonymous with 'science of martial arts'. Arch Budo 2023: 19:193-204
60. Kalina RM. BUDO & INNOAGON – historical complexity but similar missions. Arch Budo J In Agon 2024; 20: 1-15
61. Kruszewski A, Cherkashin I, Kruszewski M et al. Interpretation of Chinese Hand-to-Hand Fighting Systems and Therapeutic Exercises From the Perspective of the INNOAGON Methodology. Human Factors in Sports, Performance and Wellness 2024; 150: 74-83
62. Piepiora AP. INNOAGON Generation Born After 2025 – Alternative Recommended by Science. Human Factors in Sports, Performance and Wellness 2024; 150: 84-92
63. Martens R. Successful Coaching. 3rd ed. London: Human Kinetics; 2004
64. Dictionary of Sport and Exercise Science. Over 5,000 Terms Clearly Defined. London: A & B Black; 2006
65. Kent M. The Oxford Dictionary of Sports Science and Medicine. Oxford-New York- Tokyo: Oxford University Press; 1994
66. Bradley J, Kerr S, Bowmaker D, Gomez J-F. Review of Shoulder Injuries and Shoulder Problems in Competitive Swimmers. American Journal of Sports Science and Medicine 2016; 4 (3): 57-73
67. Pszczołowski T. Mała encyklopedia prakseologii i teorii organizacji. Wrocław-Gdańsk; Zakład Narodowy imienia Ossolińskich. Wydawnictwo, 1978. Polish; the indices of terms: English, French, German, Russian

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