



Genç Yüzücülerde Spor Performansı ve Omuz Eklemi Hareket Açıklığının İncelenmesi

Kubilay ÇİMEN¹, Görkem AÇAR², Duran ARSLAN³, Sinan DEMİRCİ⁴

¹İstanbul Gelişim Üniversitesi, Spor Bilimleri Fakültesi, Spor Yöneticiliği Bölümü, İstanbul, Türkiye

<https://orcid.org/0000-0003-1427-120X>

²İstanbul Gelişim Üniversitesi, Spor Bilimleri Fakültesi, İstanbul, Türkiye

<https://orcid.org/0000-0002-0970-8625>

³İstanbul Gelişim Üniversitesi, Spor Bilimleri Fakültesi, İstanbul, Türkiye

<https://orcid.org/0000-0002-9660-5009>

⁴İstanbul Gelişim Üniversitesi, Spor Bilimleri Fakültesi, Rekreasyon Bölümü, İstanbul, Türkiye

<https://orcid.org/0000-0002-6061-4325>

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ORJINAL MAKALE

Özet

Yüzme, tekrarlayıcı üst ekstremité hareketlerini içeren bir spordur ve omuz eklemi hareket açıklığı (EHA), yüzme performansının önemli bir belirleyicisidir. Bu çalışmanın amacı, elit ve amatör yüzücüler arasında omuz eklemi hareket açıklığı ile 50 metre yüzme performansı arasındaki farkları araştırmak ve bu parametreler arasındaki ilişkiyi değerlendirmektir. Çalışmaya yaşları 12–18 arasında değişen toplam 46 genç yüzücü (23 elit, 23 amatör) katılmıştır. Omuz eklemi hareket açıklığı (fleksiyon, ekstansiyon, abduksiyon, addüksiyon, internal ve eksternal rotasyon) gonyometre ile ölçülmüştür. Performans değerlendirmesi, en iyi 50 metre yüzme derecesine göre yapılmıştır. Grup karşılaştırmaları için bağımsız örneklem t-testi ve Mann–Whitney U testi, ilişkilerin incelenmesinde ise tek yönlü ANOVA ve Spearman korelasyon testleri kullanılmıştır. Elit genç yüzücülerin tüm omuz hareketlerinde anlamlı derecede yüksek EHA değerlerine ve daha iyi 50 metre performansına sahip oldukları belirlenmiştir ($p < .001$). En belirgin fark sağ omuz internal rotasyonunda gözlenmiştir ($t = -18.531$, $p < .001$; Ortalama Fark = -22.261°). Tüm yönlerde omuz EHA değerleri ile 50 metre yüzme süresi arasında negatif korelasyon bulunmuştur ($p < .001$). Omuz hareket açıklığının artması, yüzme performansının temel belirleyicilerinden biridir. Bu nedenle, hareket açıklığını geliştirmeye yönelik düzenli değerlendirme ve antrenmanlar hem performans artışı hem de yaralanmaların önlenmesi açısından önem taşımaktadır.

Anahtar kelimeler: Omuz Eklemi Hareket Açıklığı, Yüzme Performansı, Atletik Performans, Biyomekanik, Genç Yüzücüler

The Investigation of Sports Performance and Shoulder Joint Mobility in Young Swimmers

Kubilay ÇİMEN¹, Gökem AÇAR², Duran ARSLAN³, Sinan DEMİRCİ⁴

¹Istanbul Gelişim University, Faculty of Sport Sciences, Department of Sports Management, Istanbul, Türkiye

<https://orcid.org/0000-0003-1427-120X>

²Istanbul Gelişim University, Faculty of Sport Sciences, Istanbul, Türkiye

<https://orcid.org/0000-0002-0970-8625>

³Istanbul Gelişim University, Faculty of Sport Sciences, Istanbul, Türkiye

<https://orcid.org/0000-0002-9660-5009>

⁴Istanbul Gelişim University, Faculty of Sport Sciences, Department of Recreation, Istanbul, Türkiye

<https://orcid.org/0000-0002-6061-4325>

Abstract

Swimming is a sport involving repetitive upper extremity movements, and shoulder joint range of motion (ROM) is a key determinant of swimming performance. The aim of this study was to investigate differences in shoulder joint ROM and 50 m swimming performance between elite and amateur swimmers and to evaluate the relationship between these parameters. A total of 46 young swimmers, including 23 elite and 23 amateur swimmers aged 12–18, participated in the study. Shoulder joint range of motion (flexion, extension, abduction, adduction, internal and external rotation) was measured using a goniometer. Performance was assessed based on the best 50 m swimming time. Independent t-tests and Mann–Whitney U tests were used for group comparisons, while one-way ANOVA tests and Spearman correlation tests were used for relationship analyses. Elite young swimmers had significantly higher ROM values and better 50 m performance in all shoulder movements ($p < .001$). The most significant difference was observed in right shoulder internal rotation ($t = -18.531$, $p < .001$; Mean Difference = -22.261°). A negative correlation was found between shoulder ROM and 50 m time in all directions ($p < .001$). Increased shoulder range of motion is a key parameter in swimming performance. Regular assessment and training targeting mobility are important for both performance improvement and injury prevention.

Keywords: *Shoulder Joint Range of Motion, Swimming Performance, Athletic Performance, Biomechanics, Young Swimmers*

Introduction

Swimming, due to its nature involving repetitive upper extremity movements, is one of the sports with the highest incidence of shoulder pain and injuries among athletes (Hill et al., 2015). The prevalence of shoulder pain in swimmers ranges from 40% to 91%, and this condition negatively impacts training and competition performance (Hill et al., 2015; Cejudo et al., 2019). The shoulder joint is a critical structure that directly contributes to swimming performance due to its wide range of motion; however, this flexibility also makes the joint more susceptible to injuries (Neumann, 2002).

Studies on shoulder biomechanics have shown that the coordination of static and dynamic stabilisers is crucial for joint health and functionality (Hayes et al., 2002). Struyf et al. (2017) emphasised that shoulder muscle imbalances and postural abnormalities increase the risk of injury in swimmers (Struyf et al., 2017). Additionally, Cejudo et al. (2019) identified limited abduction range of motion in the shoulder joint as an important risk factor for pain (Cejudo et al., 2019). Tate et al. (2012) have pointed out that shoulder pain experienced by swimmers throughout their lives may lead to long-term functional impairments (Tate et al., 2020).

However, significant limitations are evident in the literature. Firstly, most existing studies focus on pain and injury; however, the causal relationship between shoulder joint mobility and sports performance has not been sufficiently investigated (Hill et al., 2015; Pink & Tibone, 2000; Ciullo & Stevens, 1989; Weldon & Richardson, 2001). Additionally, there is a lack of comparative data on shoulder joint mobility and swimming performance between elite and amateur young swimmers. This situation creates a scientific gap in the development of specific training approaches and injury prevention strategies.

In the existing literature, shoulder joint biomechanics in swimmers has predominantly been examined within the context of pain, injury risk, and pathological adaptations, whereas the direct relationship between shoulder joint range of motion and sports performance has been investigated in a limited number of studies, primarily involving adult athlete populations. Particularly in younger age groups, studies that compare elite and amateur swimmers, quantitatively assess shoulder joint mobility across all planes of motion, and examine its association with sprint swimming performance using a comprehensive approach remain scarce, representing a clear gap in the literature. In this context, the present study provides a multidimensional analysis of the relationship between shoulder joint range of motion and performance in young swimmers aged 12–18 years, delineates differences between elite and amateur levels, and offers original and practice-oriented scientific evidence regarding the determinant role of shoulder mobility in swimming performance.

The aim of this study is to investigate the relationship between shoulder joint mobility and sports performance in young swimmers. The research aims to reveal the differences between elite and amateur swimmers and to provide original scientific data for the optimisation of shoulder health and performance. It is anticipated that the findings obtained within this scope

will contribute to the protection of athlete health and the development of performance-enhancing training programmes.

Research Questions

1. Do shoulder joint range of motion (flexion, extension, abduction, adduction, internal rotation, and external rotation) parameters differ between elite and amateur young swimmers aged 12–18 years?
2. Is 50-m swimming performance significantly different between elite and amateur young swimmers?
3. Is there an association between shoulder joint range of motion and 50-m swimming performance in young swimmers?
4. Which specific shoulder joint motion(s) show the strongest relationship with sprint swimming performance?
5. Are shoulder joint range of motion parameters associated with anthropometric characteristics such as arm length and stroke length in young swimmers?

Material and Methods

Research Design and Model

This study was conducted using a comparative cross-sectional and correlational research design. A cross-sectional model was adopted to investigate the relationship between shoulder joint mobility and sports performance among elite and amateur young swimmers. The study was conducted with the approval of the Istanbul Gelişim University Non-Clinical Research Ethics Committee dated 19 December 2024 and numbered 2024-20.

The sample size was determined using the G*Power 3.1.9.7 programme. In the power analysis conducted for the independent samples t-test, an effect size of 0.750 ($d=0.750$), a 5% error margin ($\alpha=0.05$), and 80% power ($1-\beta=0.80$) were considered, and a total of 46 participants were targeted, with 23 elite and 23 amateur swimmers in each group. (Matthews et al., 2017).

Inclusion criteria for the study included participants being aged 12–18 years, actively participating in swimming at an elite or amateur level, and having previously participated in at least one official swimming competition. Conversely, exclusion criteria include a history of orthopaedic disorders, the presence of a previously diagnosed or currently treated shoulder problem, and a history of surgical intervention in the shoulder region. These criteria were applied to ensure the homogeneity of the sample and the reliability of measurements.

Participants

A total of 58 young swimmers were included in the study. Twelve young swimmers who did not meet the inclusion criteria were excluded from the study, resulting in a total of 46 young swimmers, comprising 23 amateurs and 23 elites (Figure 1). Descriptive statistics regarding the

participants' age, height, weight, BMI, and years of swimming experience are presented in Figure 2. The gender distribution of the participants is shown in Table 1. Among male participants, 56.5% were amateurs and 43.5% were elite, while among female participants, 43.5% were amateurs and 56.5% were elites. There were 23 males and 23 females in both groups.

The distribution of participants according to their preferred swimming styles is shown in Table 2. The distribution of different swimming styles, such as freestyle, butterfly, backstroke, and breaststroke, is reported in detail at the group level, and the diversity between groups is revealed. In this context, the study sample shows diversity in terms of both gender and swimming style and provides a suitable basis for comparisons between amateur and elite swimmers.

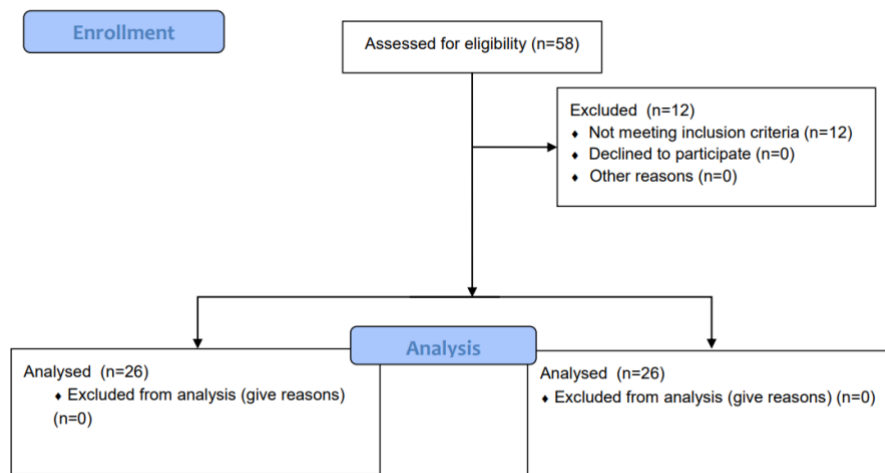


Figure 1. CONSORT FLOW diagram of swimmers' distribution

Table 1 summarises the distribution of participants by gender and group. A total of 46 participants were included, equally divided between amateur ($n = 23$) and elite ($n = 23$) swimmers. Among males, 56.5% were in the amateur group and 43.5% in the elite group. Conversely, among females, 43.5% were amateurs and 56.5% elites. This indicates a balanced gender distribution with a relatively even gender representation across groups.

Table 1: Distribution of participants by gender and group

Gender	Group	Count	% within Gender
Male	Amateur	13	56.5
	Elite	10	43.5

Female	Amateur	10	43.5
	Elite	13	56.5
Total	Amateur	23	50.0
	Elite	23	50.0

Table 2 shows the distribution of swimming styles across amateur and elite groups. Freestyle was more common among elites (66.7%), while butterfly and breaststroke were more frequently observed in amateurs (66.7% and 61.5%, respectively). Backstroke was equally distributed between groups (50.0% each). Overall, both groups had equal total participation ($n = 23$), indicating a diverse but balanced representation of swimming styles across experience levels.

Table 2: Distribution of swimming styles by group

Swimming Style	Group	Count	% within Swimming Style
Freestyle	Amateur	5	3
	Elite	10	66.7
Butterfly	Amateur	4	66.7
	Elite	2	33.3
Backstroke	Amateur	6	50.0
	Elite	6	50
Breaststroke	Amateur	8	61.5
	Elite	5	38.5
Total	Amateur	23	50.0
	Elite	23	50

Tests and Measurement Methods Used

- **Shoulder Joint Mobility and Range of Motion:** The range of motion for shoulder flexion, extension, abduction, adduction, internal rotation, and external rotation was measured using a goniometer. Measurements were taken in a bipedal position with the fixed and moving arms aligned with the goniometer, and three repetitions were performed for each movement, with average values recorded (Soucie et al., 2011).
- **Upper Extremity Anthropometric Measurements:** Anthropometric data of the upper extremities, such as arm length and arm span, were obtained from the athletes (Uzun et al., 2019).
- **Swimming Performance Measurement:** Participants were asked to swim 50 metres according to their swimming styles, and their times were recorded with a stopwatch. The test was repeated three times, and the best time was recorded (Smith et al., 2002).

The data collection process was conducted through individual applications with young swimmers who voluntarily participated in the study. All measurements were performed by an experienced physiotherapist under the same environmental conditions and following the same standard protocol. Participants performed the necessary warm-up exercises before shoulder mobility measurements.

All measurements were initially performed on the dominant upper extremity, followed by the non-dominant side, to ensure consistency across participants. To minimize the potential influence of acute fatigue, all assessments were conducted prior to the athletes' regular training sessions on the same day.

Statistical Analysis

The data obtained in the study were analysed using the IBM SPSS Statistics 26.0 (IBM Corp., Armonk, NY, USA) programme. Descriptive statistics included mean, standard deviation, and percentage values for continuous variables. To examine differences between amateur and elite swimmers, t-tests were used for independent samples when parametric assumptions were met, and Mann-Whitney U tests were used when normality assumptions were violated. The normality of the data distribution was assessed using the Shapiro-Wilk test, and the homogeneity of variance was evaluated using the Levene test. One-way analysis of variance (ANOVA) was used for comparisons involving three or more groups, such as swimming style. Correlation analyses were conducted to determine the relationship between shoulder joint range of motion and 50-metre swimming performance. Since the relevant variables did not show a normal distribution, the relationship between variables was analysed using the Spearman rank correlation coefficient (ρ). This analysis provided important insights into which joint ranges of motion are more closely related to swimming performance. The significance level was set at $p < 0.05$ for all analyses.

In the present study, ANOVA and Spearman correlation analyses were used to address distinct but complementary analytical objectives. While the primary aim was not to compare predefined subgroups, ANOVA was applied as an exploratory procedure to examine whether shoulder joint

range of motion and performance variables differed across swimmer subgroups (e.g., swimming style), thereby assessing the potential confounding effect of subgroup-related variability on the main outcomes. In contrast, Spearman correlation analysis was employed to evaluate the monotonic associations between shoulder joint range of motion parameters and sprint swimming performance, independent of subgroup classification, and was selected due to non-normal data distributions. The combined use of these statistical approaches allowed both the assessment of potential between-group variability and the investigation of overall performance-related associations, providing a comprehensive and methodologically justified analytical framework.

Result

The current study aimed to compare biomechanical and anthropometric characteristics, particularly focusing on shoulder joint ROM and swimming performance metrics, between amateur and elite swimmers. A series of independent samples t-tests, Mann–Whitney U tests, one-way ANOVA, and Spearman correlation analyses were conducted to identify intergroup differences and associations among key variables. The findings revealed that elite swimmers demonstrated significantly greater shoulder ROM, superior sprint performance over 50 metres, and longer stroke and arm lengths compared to their amateur counterparts. Despite no statistically significant differences in height, weight, or BMI between the groups, robust negative correlations were identified between shoulder mobility and 50-metre swim time, underscoring the importance of shoulder flexibility—particularly in internal rotation and abduction—for enhanced swimming performance. These results provide evidence for sport-specific morphological and functional adaptations associated with elite-level training.

Table 3 summarizes the comparison of shoulder joint range of motion and selected sociodemographic and performance-related variables between amateur and elite swimmers. Group comparisons were conducted using independent-samples t-tests or Mann–Whitney U tests according to normality and homogeneity of variance assumptions. Elite swimmers demonstrated significantly greater shoulder joint mobility across all measured planes of motion on both sides ($p < .001$), indicating consistently higher flexion, extension, abduction, adduction, and rotational range of motion compared with amateurs. The largest between-group difference was observed in right shoulder internal rotation ($t = -18.531$, $p < .001$; mean difference = -22.261°).

With respect to performance-related variables, elite swimmers showed significantly longer swimming experience ($U = -10.659$, $p < .001$) and superior 50-m swimming performance ($U = 22.114$, $p < .001$). In addition, stroke length ($t = -7.691$, $p < .001$) and bilateral arm lengths ($p < .01$) were significantly greater in the elite group, while no significant differences were found for general anthropometric characteristics such as height, body mass, or BMI ($p > .05$). Collectively, these findings suggest that elite-level training is primarily associated with enhanced shoulder joint mobility and performance-specific anthropometric characteristics rather than differences in general body composition.

Table 3: Comparison of shoulder joint range of motion and sociodemographic data between amateur and elite swimmers

Variable	t/z	df	p	Mean Difference	SE Difference	95% CI Lower	95% CI Upper	Effect size
Years of Swimming ^u	-10.659	27.3	<.001*	-5.304	0.498	-6.325	-4.284	1.57
50 m Performance ^u	22.114	35.497	<.001*	18.622	0.842	16,913	20.33	3.26
Shoulder Flexion (R) ^u	-7.792	38.863	<.001*	-12.391	1.59	-15.608	-9.174	1.15
Shoulder Flexion (L) ^t	-6.248	42.209	<.001*	-9.043	1.447	-11,964	-6,123	0.92
Shoulder Extension (R) ^u	-8.745	39.62	<.001*	-14.304	1.636	-17.611	-10.998	1.29
Shoulder Extension (L) ^u	-7,164	39.7	<.001*	-11.652	1.626	-14.94	-8.364	1.06
Shoulder Abduction (R) ^u	-8.95	34.106	<.001*	-20.609	2.303	-25.288	-15.93	1.32
Shoulder Abduction (L) ^u	-7.096	34.825	<.001*	-15.957	2.249	-20.522	-11.391	1.05
Shoulder Adduction (R) ^u	-7.683	24.581	<.001*	-13.391	1.743	-16.984	-9.798	1.13
Shoulder Adduction (L) ^u	-10.14	26.43	<.001*	-15.261	1.504	-18.351	-12.171	1.5
Shoulder Internal Rotation (R) ^u	-18.53	27.314	<.001*	-22.261	1.201	-24.724	-19.797	2.73
Shoulder Internal Rotation (L) ^u	-18.58	29.02	<.001*	-19.348	1.041	-21.477	-17.218	2.74
Shoulder External Rotation (R) ^u	-8.431	37.17	<.001*	-12.304	1.459	-15.261	-9.348	1.24
Shoulder External Rotation (L) ^u	-5.359	36.337	<.001*	-8.13	1.517	-11.206	-5.055	0.79

Stroke Length^t	-7.691	43.165	<.001*	-14.522	1.888	-18.329	-10.714	1.14
Right Arm Length^t	-3.407	42.619	<.001*	-3.522	1.034	-5.607	-1.437	0.50
Left Arm Length^t	-3.933	43.096	<.001*	-3.87	0.984	-5.854	-1.885	0.58
Age (year)^u	2.605	43.077	0.013*	1.348	0.517	0.304	2.391	0.38
Height (cm)^u	0.464	43.868	0.645	1.087	2.342	-3.633	5.807	0.07
Weight (kg)^u	0.904	42.841	0.371	2.478	2.741	-3.049	8.006	0.13
BMI (kg/m²)^t	0.23	27.92	0.820	0.208	0.906	-1.6479	2.0653	0.03

T: Independent t-test, U: Mann Whitney U test *p<0.05

Table 4 presents the one-way ANOVA results comparing shoulder ROM and performance variables among different swimmer subgroups. The analysis revealed that none of the variables showed statistically significant differences across groups ($p > .05$).

Although there were numerical differences in certain parameters, such as right shoulder abduction ($F = 1.908$, $p = .143$) and left internal rotation ($F = 1.596$, $p = .205$), these did not reach statistical significance. The 50-meter performance time also showed no significant difference between groups ($F = 0.855$, $p = .472$), indicating a relatively homogeneous distribution of sprint performance regardless of subgroup classification.

All other ROM parameters, including shoulder flexion, extension, adduction, and external rotation for both sides, showed F-values well below the threshold for significance (p-values ranging from .300 to .992), suggesting consistent shoulder mobility across the subgroups compared.

These findings suggest that shoulder joint ROM and 50 m swimming performance were not significantly influenced by subgroup classification, implying that factors other than training type or style distribution may account for performance and mobility outcomes.

Table 4: Results for shoulder ROM and performance variables

Variable	Sum of Squares (Between)	df (Between)	Mean Square (Between)	Sum of Squares (Within)	df (Within)	Mean Square (Within)	F	p	η^2
50 m Performance	250.088	3	83.363	4096.575	42	97.537	0.855	0.472	0.05
Shoulder Flexion (R)	44.186	3	14.729	3001.227	42	71.458	0.206	0.892	0.01
Shoulder Flexion (L)	165.484	3	55.161	1835.124	42	43.693	1,262	0.300	0.08
Shoulder Extension (Right)	125.063	3	41.688	3.581.741	42	85.28	0.489	0.692	0.03
Shoulder Extension (L)	209.6	3	69.867	2690.4	42	64.057	1.091	0.364	0.07
Shoulder Abduction (R)	907.742	3	302.581	6659.214	42	158.553	1.908	0.143	0.11
Shoulder Abduction (L)	324.296	3	108.099	5162.16	42	122.909	0.88	0.459	0.05
Shoulder Adduction (R)	8.021	3	2.674	3591.631	42	85.515	0.031	0.992	0.01
Shoulder Adduction (L)	84.903	3	28.301	3738.51	42	89.012	0.318	0.812	0.02
Shoulder Internal Rotation (R)	328.53	3	109.5	6100.427	42	145.248	0.754	0.526	0.05
Shoulder Internal Rotation (L)	496.747	3	165.582	4356.753	42	103.732	1.596	0.205	0.10
Shoulder External Rotation (Right)	149.879	3	49.96	2668.926	42	63.546	0.786	0.508	0.05
Shoulder External Rotation (L)	36.701	3	12.234	1888.017	42	44,953	0.272	0.845	0.01

* $p < 0.05$

Table 5 demonstrates the intercorrelations between 50-meter performance time and various shoulder range of motion (ROM) parameters. The analysis revealed strong and statistically significant negative correlations between performance time and all measured ROM variables ($p < .01$). The strongest associations were observed between 50-metre performance and right shoulder internal rotation ($r = -0.909$), left shoulder internal rotation ($r = -0.908$), right shoulder abduction ($r = -0.831$), and right shoulder extension ($r = -0.829$). These findings indicate that greater shoulder mobility, particularly in rotational and abduction movements, is associated with better swimming performance (i.e., reduced 50 m time). Additionally, most ROM variables were strongly interrelated with one another ($r > .60$, $p < .01$), suggesting high bilateral symmetry and functional integration across different shoulder movements. The overall pattern of correlations underscores the importance of comprehensive shoulder mobility in facilitating efficient biomechanical function and enhancing sprint performance in competitive swimmers.

The correlation matrix presented in Table 5 demonstrates strong associations among shoulder joint range of motion variables, which may partly reflect shared biomechanical characteristics and common variance across different planes of movement. Given the high intercorrelations observed, the possibility of multicollinearity should be considered when interpreting the strength of individual relationships between specific range of motion parameters and swimming performance. These findings suggest that shoulder mobility should be viewed as a multidimensional construct rather than as isolated joint movements. Accordingly, the strong correlations observed likely represent an integrated functional profile of the shoulder complex, shaped by sport-specific training adaptations, rather than independent effects of single motion planes. This consideration underscores the importance of cautious interpretation of individual correlation coefficients and supports the use of comprehensive mobility assessments in future multivariate or predictive modeling studies.

Table 5: Matrix for shoulder ROM and performance variables

Variable	50 m Performan ce	Shoulde r Flexion (R)	Shoulde r Flexion (L)	Shoulde r Extensio n (R)	Shoulde r Extensio n (L)	Shoulder Abductio n (R)	Shoulder Abductio n (Left)	Shoulder Adductio n (Right)	Shoulder Adductio n (L)	Shoulde r Internal Rotatio n (Right)	Shoulde r Internal Rotatio n (Left)	Shoulde r Externa l Rotatio n (Right)	Shoulde r Externa l Rotatio n (L)
50 m Performan ce	1	-.784**	-.0772**	-.829**	-.798**	-.831**	-.777**	-.729**	-.792**	-.909**	-.908**	-.816**	-.646**
Shoulder Flexion (R)		1	.607**	.691**	.615**	.592**	.689**	.583**	.676**	.751**	.656**	.773**	.733**
Shoulder Flexion (L)			1	.719**	.711	.715**	.602**	.424**	.458**	.585**	.619**	.682**	.687**
Shoulder Extension (R)				1	.680**	.686	.547**	.528**	.725**	.765**	.725**	.587**	.599**
Shoulder Extension (L)					1	.822**	.649**	.490**	.620**	.629**	.687**	.800**	.417**
Shoulder Abduction (R)						1	.590**	.553	.664**	.745**	.758**	.740**	.446**
Shoulder Abduction (L)							1	.659**	.699**	.666	.711**	.693**	.598**
Shoulder Adduction (R)								1	.708**	.706**	.693**	.634**	.455**
Shoulder Adduction (L)									1	.836**	.788**	.544**	.378**
Shoulder Internal										1	.892**	.658	.558**

Rotation (R)			
Shoulder Internal Rotation (L)	1	.673**	.541**
Shoulder External Rotation (R)		1	.713**
Shoulder External Rotation (L)			1

*p<0.05, **p<0.01

Discussion, Conclusions, and Recommendations

In this study, elite swimmers were found to exhibit significantly greater shoulder ROM and superior swimming performance compared with amateur swimmers. In particular, the consistently higher ROM observed in fundamental movements such as shoulder flexion, extension, abduction, adduction, and internal and external rotation among elite swimmers suggests an association between long-term training exposure, repetitive upper-extremity use, and sport-specific structural and functional adaptations. These findings are in line with previous literature highlighting a close relationship between shoulder mobility characteristics and performance outcomes in upper extremity-dominant sports such as swimming.

Riemann et al. (2011) reported that competitive swimmers tend to demonstrate increased external rotation and reduced internal rotation of the dominant shoulder, with these adaptations becoming more pronounced at higher performance levels. Such rotational imbalances have been discussed in the literature as potential risk factors for shoulder injury over time. Similarly, Bak and Magnusson (2000) observed that decreases in internal rotator muscle strength were associated with a higher injury risk in elite swimmers with shoulder pain. In the same study, internal rotation ROM was reported to be reduced, while external rotation ROM was increased across groups, findings that are generally consistent with the mobility profiles observed in the present study.

Nevertheless, interpreting increased joint range of motion as a direct determinant of swimming performance would be an oversimplification. Previous research indicates that neuromuscular factors, including muscle strength, muscular endurance, and proprioceptive control, are also closely associated with both performance and injury risk in swimmers. Beach et al. (1992) emphasised that reduced endurance of the external rotator muscles is associated with shoulder pain onset, suggesting that imbalances between mobility and muscular control may compromise joint stability. From this perspective, the potential performance-related benefits associated with greater shoulder mobility appear to be dependent on adequate neuromuscular control and stabilisation capacity.

Age and training history also appear to be important factors associated with variations in joint range of motion. In the present study, elite young swimmers with longer training histories demonstrated higher ROM values. Jansson et al. (2005) reported that general joint laxity and shoulder laxity are frequently observed in swimmers who initiate training during growth periods, which may contribute to increased ROM measures. Similarly, Junge et al. (2016) found that active shoulder abduction is associated with hypermobility in swimmers aged 10–15 years, indicating that such structural characteristics may be related to performance characteristics while simultaneously increasing susceptibility to injury. Accordingly, these findings underline the importance of preventive strategies focusing on shoulder girdle strengthening and neuromuscular control, particularly in hypermobile young athletes, to support long-term athletic health.

In the present study, significant negative correlations were observed between 50 m swimming time and all shoulder ROM measurements, indicating that greater shoulder mobility is associated with better sprint swimming performance. These associations suggest that higher ROM values may be related to stroke characteristics such as stroke length and propulsive efficiency, which are commonly linked to faster swimming times, rather than implying a direct causal effect. In this context, Rezaei et al. (2025) reported that range of motion– and posture-focused exercise interventions were accompanied by improvements in swimming performance and reductions in shoulder pain, supporting the relevance of shoulder ROM in relation to technical proficiency and biomechanical efficiency.

Moreover, the positive correlations identified between shoulder joint mobility and anthropometric variables, including arm length and stroke length, warrant consideration. Raffini et al. (2024) examined the influence of shoulder kinematics on swimming performance and demonstrated that shoulder movement patterns are closely associated with both technical execution and propulsive force generation. These findings underscore the importance of evaluating structural length parameters and functional range of motion in conjunction, as their combined characteristics appear to be related to performance-related outcomes in swimming.

Several limitations should be acknowledged when interpreting the findings of this study. First, the cross-sectional design does not allow for causal inferences regarding the relationship between shoulder joint ROM and swimming performance; therefore, longitudinal or interventional studies are needed to clarify the directionality of these associations. Second, the sample comprised only young swimmers aged 12–18 years from a limited geographic region, which may limit the generalizability of the results to other age groups, competitive levels, or populations. Third, swimming performance was assessed exclusively using a 50 m sprint, which, although appropriate for evaluating explosive performance, does not reflect endurance-based or multi-event performance demands. Fourth, despite the inclusion of anthropometric and biomechanical variables, other relevant factors such as muscle strength, muscular endurance, proprioception, and training load were not directly measured. Finally, although all goniometric measurements were conducted by an experienced physiotherapist, the use of manual assessment techniques may still be subject to inter- and intra-rater variability compared with instrumented or motion capture–based systems.

The findings of this study indicate that shoulder joint range of motion is closely associated with swimming performance in young swimmers, with internal rotation and abduction emerging as particularly influential for 50-m sprint performance. The significantly greater ROM observed in elite swimmers compared with amateurs suggests that long-term, structured training contributes to sport-specific functional adaptations of the shoulder joint. However, improvements in mobility alone may not be sufficient to sustain performance gains and should be considered alongside muscular strength, neuromuscular control, and joint stability. Collectively, these results highlight the importance of individualized assessment and training strategies to optimize performance while protecting shoulder health in young swimmers.

From a practical perspective, the present findings highlight the importance of regularly monitoring shoulder joint range of motion in young swimmers as part of routine performance

and health assessments. For coaches, incorporating mobility-oriented screening alongside technical and conditioning programs may help identify swimmers with reduced or asymmetrical shoulder mobility that could be associated with suboptimal performance characteristics. For physiotherapists, the strong associations observed between shoulder ROM, sprint performance, and anthropometric variables underscore the need for individualized intervention strategies that integrate mobility, neuromuscular control, and shoulder girdle stabilization rather than focusing on range of motion in isolation. Such an integrated approach may support performance optimization while simultaneously contributing to long-term shoulder health and injury risk management in young swimmers.

In conclusion, this study demonstrates that shoulder joint range of motion is a decisive factor in swimming performance. However, it is clear that increased mobility alone does not guarantee performance improvement, and that numerous factors such as neuromuscular control, strength balance, and training duration must be evaluated together. Regular assessment of range of motion, especially in individuals who start sports at a young age, is important for both optimal development and the prevention of potential injuries. In this regard, it is recommended that training plans be designed taking into account individual morphological and functional characteristics in order to improve performance and protect athlete health.

Ethics Committee Approval Information

The study was conducted with the approval of the Istanbul Gelisim University Non-Clinical Research Ethics Committee dated 19 December 2024 and numbered 2024-20.

Author Contribution

Concept: GA, KÇ, SD; **Design:** KÇ, DA; **Data collecting:** GA, KÇ, DA,SD; **Literature review:** GA, KÇ, DA; **Writing:** GA, DA,SD; **Critical review:** KÇ.

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Statement of Conflict

The author(s) have no conflict of interest to declare regarding the research

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