

Original Research

The Effects Of Differing Density Of Swim-Training Sessions On Shoulder Range Of Motion and Isometric Force Production In National and University Level Swimmers

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Background

Well-developed physical qualities (i.e., greater load capacity) in athletes can provide protection against injuries. Although higher competitive level swimmers have more developed physical qualities, no studies have investigated how physical qualities of the shoulder respond to a swim-training session in different competitive levels.

Purpose

To compare baseline shoulder external rotation range of motion (ER ROM) and isometric peak torque of the shoulder internal rotators (IR) and external rotators (ER) between national and university level swimmers with differing training volumes. To compare the post-swim changes of these physical qualities between groups.

Study design

Cross-sectional.

Methods

Ten male swimmers (age= 18.7 ± 1.2 years) were divided into high-load (N= 5 national-level, weekly swim-volume= 37.0 ± 2.7 km) and low-load groups (N= 5 university-level, weekly swim-volume= 6.8 ± 1.8 km). For each group, shoulder active ER ROM and isometric peak torque of the shoulder IR and ER were measured before and immediately after a high-intensity swim-training session (for each group, the hardest swim-session of the week was analyzed). The results were evaluated by the level of significance (p-value), effect size, and whether changes exceeded the measurement error.

Results

University-level swimmers had lower baseline ER torque (p= 0.006; d= 2.55) and IR torque (p= 0.011; d= 2.42) than national-level swimmers. For post-swim analysis, ER ROM decreased more in university swimmers (change= -6.3° to -8.4°; d= 0.75-1.05) than national counterparts (change= -1.9° to -5.7°; d= 0.43-0.95). Greater drops in rotation torque were found in university swimmers (IR change= -15% to -21.0%; d= 0.83-1.66; ER change= -9.0% to -17.0%; d= 1.14-1.28) compared to national swimmers (IR change= -10.0% to -13.0%; d= 0.61-0.91; ER change= -3.7% to -9.1%; d= 0.50-0.96). The average change of all tests in university swimmers exceeded the minimal detectable change (MDC), whereas in national level swimmers some tests exceeded the MDC. Despite this, only post-swim ER torque in the dominant side (p= 0.003; d= 1.18) was significantly lower in university swimmers (possibly due to the small sample size).

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Conclusions

University swimmers have less baseline shoulder external and internal rotator torque and had greater drops of all shoulder physical qualities after a swim-training session, which may have implications for injury risk. However, due to the sample size, the results have to be interpreted with caution.

Level of evidence

3

INTRODUCTION

The shoulder is the most commonly injured body part in swimmers with a prevalence reported as high as 91%.¹ Level of competition has been reported as a potential nonmodifiable risk factor for shoulder pain in this population.² This might be explained as swimmers of a higher competitive level are exposed to greater chronic loads (e.g. weekly swim-training volume and number of training sessions).³ However, higher levels of competition have been also associated with more developed physical qualities such as aerobic capacity and shoulder strength,^{4,5} which might be also protective against injury in swimmers ('training load-injury paradox').⁶ Feijen et al.⁷ found that club-level swimmers had a higher risk of shoulder pain than regional-level counterparts during a two-year follow-up. A possible explanation for this is that fitter and stronger athletes (i.e., higher load capacity) can better tolerate the amount of and changes in workloads.^{8,9}

Some authors have investigated how swimmers respond to training loads.¹⁰⁻¹⁵ These researchers found that a swim-training session negatively affects shoulder physical qualities such as rotation strength,¹² rotation ROM,¹⁰⁻¹² pectoralis minor length,¹⁰ and joint position sense.^{10,11} Since some of these physical qualities have been considered potential risk factors for shoulder pain in swimmers,^{2,14} their acute impairments can increase the risk of shoulder injury.¹⁵ The injury-etiology model proposed by Windt & Gabbett¹⁵ suggests that the risk of injury can increase as a result of training loads applied and the negative effects on modifiable risk factors (e.g., physical qualities). Although these studies investigated different levels of competition, it is difficult to make comparisons as the swim-sessions studied varied in terms of volume, intensity, and time. Therefore, it is unknown whether higher-level swimmers (i.e., stronger and fitter athletes) have less significant decreases in physical qualities than lower-level counterparts after a similar swim-training session.

To date, some authors have shown that swimmers of a higher competitive level have more developed shoulder physical qualities.^{4,5} However, no studies have compared the postswim changes in shoulder physical qualities between different levels of competition. Investigating this can help to understand whether higher chronic loads and well-developed physical qualities affect post-training shoulder responses. This might have implications in the prevention of shoulder pain in specific groups. The primary aim of this study was to compare the baseline differences in shoulder ER ROM and isometric peak torque of the shoulder internal and external rotators between university and national level

swimmers with differing training volumes. A secondary aim was to compare the postswim changes of these physical qualities between groups. It was hypothesized university swimmers would have less developed physical qualities at baseline. Also, that these physical qualities would be more affected after the training session in university swimmers.

MATERIALS AND METHODS

PARTICIPANTS

A sample of ten male participants was included in the study. Participants were divided into two groups according to their level of competition: high-load (university level; N = 5) and low-load (national level; N = 5). Participants of both groups were matched by gender, age, and years of swim experience, but differed in training volume. All swimmers trained within the same group during the year, completed the same practices regularly, and participated in either university or national championships. The exclusion criteria included a history of shoulder surgery, shoulder pain at the time of the study, and any pain in the two weeks prior to study that interfered with the ability to train or compete fully.¹⁰ All participants provided written informed consent. This study was approved by the university's ethics board and conducted in accordance with the Declaration of Helsinki (Ref.no.HSR1718-100).

PROCEDURES

The same researcher (MY) performed all the tests in both groups. For each swimmer, measurements were recorded before and after a swim-training session. On the testing day, general demographic information of participants, such as sex, age, limb dominance, height, mass, and forearm length, were recorded. Before the procedure testing, participants performed a standardized land-based warm-up consisting of shoulder movements. Immediately after the warm-up, baseline measurements were recorded in the following order: shoulder ER ROM, and isometric peak torque of the shoulder internal and external rotators. All the tests were standardized, and the dominant arm was assessed first. Three subsequent testing trials of each test were performed in both limbs, and the results were averaged for further analysis. Immediately after completion of the training, swimmers exited the pool and repeated baseline testing.

INSTRUMENTATION AND OUTCOME MEASURES

Regarding shoulder-rotation ROM, only ER was measured. The reason for this was because previous authors¹⁰⁻¹² have

Table 1. Two-Hour Test-Retest Reliability for the Outcome Measures Calculated from the Pilot Study (N = 10)

Test	Side	Intraclass Correlation Coefficient (3,3) ^a (95% CI)	Standard Error of Measurement ^b	Standard Error of Measurement ^d (%)	Minimal Detectable Change ^c	Minimal Detectable Change ^d (%)
External rotation range of motion, °	Dominant	0.980 (0.922-0.995)	2.39	2.30	6.61	6.37
	Nondominant	0.990 (0.919-0.998)	1.70	1.66	4.72	4.61
External rotation torque, Nm/kg	Dominant	0.992 (0.905-0.998)	0.02	4.47	0.05	12.39
	Nondominant	0.999 (0.994-1.000)	0.01	2.04	0.02	5.65
Internal rotation torque, Nm/kg	Dominant	0.982 (0.925-0.996)	0.03	6.34	0.07	17.56
	Nondominant	0.997 (0.990-0.999)	0.01	2.62	0.03	7.26

Abbreviations: CI, confidence interval.

^a Two-way mixed model. A coefficient ≥ 0.90 is considered excellent reliability, ≤ 0.89 to ≥ 0.80 , good, ≤ 0.79 to ≥ 0.70 , moderate, and < 0.70 , low.

^b Standard deviation $\times \sqrt{1 - \text{intraclass correlation coefficient}}$.

^c Calculated as standard error of measurement $\times 1.96 \times \sqrt{2}$.

^d Standard error of measurement and minimal detectable change % were calculated by dividing their respective value with the average of the test and retest values.

found changes in ER ROM, but not in internal rotation (IR) after a swim-session. Shoulder ER ROM was measured using the 'Goniometer Pro' (5fuf5 Co, 159 Bloomfield, NJ) digital inclinometer application for the iPhone (Apple, Inc, Cupertino, CA), which is valid compared to the universal goniometer.¹⁶ Participants were positioned in supine with the shoulder in 90° of abduction and were instructed to actively rotate the limb back until the available end range.¹⁷ A towel roll was placed under the humerus to ensure correct alignment in the frontal plane. This was based on visual inspection, making sure that the humerus was levelled to the acromion process. The end range was determined by the available range without any stabilization.¹⁷

Isometric peak torque of the shoulder internal and external rotators was measured using a hand-held dynamometer (Hoggan MicroFET2; 166 Scientific LLC, Salt Lake City, UT), which is reliable and valid compared to the gold standard isokinetic dynamometry.¹⁸ Participants were positioned in supine with the shoulder in 90° of abduction. Before testing, one submaximal trial was performed to ensure correct technique. The HHD was placed on the palmar surface of the forearm for IR and on the dorsal aspect of the forearm for ER, proximal to the radioulnar joint crease. Then, participants were instructed to push against the HHD as hard as possible for three seconds, with a resting period of 10 seconds. Then, two further trials were performed. Force was converted into torque (newton meters) by multiplying the force (in newtons) by the lever arm length (meters) of the dominant and nondominant sides. Next, torque was normalized to body mass (Nm/kg) and expressed as the percentage of change between measurements. To assess muscle balance, the ratio between external and internal rotator isometric peak torque was calculated (ER: IR ratio).

Intrarater test-retest reliability for shoulder ER ROM and rotation torque was established before in a pilot study. Each measurement was taken before and after a two-hour period (average duration of a swim-training session). The intraclass correlation coefficient, standard error of measurement (SEM), and minimal detectable change (MDC) with 95% of confidence interval for each test were calculated (Table 1).

DESCRIPTION OF THE TRAINING SESSIONS

For each group, the hardest swim-session of the week was analyzed. The rationale for this was because studies have found changes in shoulder physical qualities after a high-intensity swim-training but not after a moderate to low training session.^{12,13} Based on the coach's perception, the Wednesday evening session was chosen. Both groups data were collected on the same day of the week, time, and period of the year. Both sessions lasted one hour. The only difference between sessions was the total swim-volume performed; national level swimmers performed a greater volume (3 km) than university swimmers (2 km). To assess how swimmers perceived the intensity of the training, the session-RPE (sRPE) was calculated. sRPE is a valid and reliable method to monitor training load in various sports and populations.¹⁹ Two methods of sRPE were used to quantify the internal training load: sRPE^h and sRPE^{km}.²⁰

First, the intensity of the session was quantified by the RPE based on the modified version of the category-ratio scale of Borg.²¹ Immediately after completing the training, the swimmers were asked, "how hard was your workout", using an 11-point scale with 0 corresponding to 'rest' and 10 to 'maximal' effort. For sRPE^h, the RPE score was multiplied by the session duration (min) and expressed in arbitrary units (AU). Whereas, for sRPE^{km}, the RPE was multiplied by the volume (km) and also expressed in arbitrary units (AU). This method has been used especially in swimmers to quantify internal training loads as includes the volume swam.^{20,22} Collette et al.²⁰ found that the sRPE^{km} was the strongest measure associated with the recovery-stress status of swimmers during a training season.

STATISTICAL ANALYSIS

For statistical analysis, SPSS version 25 for Windows (Inc, Chicago, IL) was used. Demographic data were initially screened for between-group differences using independent sample t-tests for normally distributed data and Mann Whitney test for non-normally distributed data. For postswim changes, results were expressed as means and

Table 2. Descriptive characteristics of participants

	University swimmers (n = 5)		National swimmers (n = 5)		Between group
	Mean \pm SD	Range (min-max)	Mean \pm SD	Range (min-max)	p- Value
Age (y)	19.4 \pm 0.9	2.0 (19 - 21)	18.0 \pm 1.2	3.0 (17.0 - 20.0)	0.062
Body mass (kg)	83.2 \pm 5.2	14.0 (75.0 - 89.0)	69.9 \pm 6.9	19.1 (60.3 - 79.4)	0.009 ^a
Height (cm)	176.0 \pm 12.3	30.0 (155.0 - 185.0)	171.8 \pm 10.5	27.0 (155.0 - 182.0)	0.578
Weekly swim-volume (km)	6.8 \pm 1.8	4.0 (6.0 - 10.0)	37.0 \pm 2.7	5.0 (35.0 - 40.0)	<0.001 ^a
Weekly training sessions (n)	2.6 \pm 0.9	2.0 (2- 4)	8.2 \pm 1.1	2.0 (8-9)	<0.001 ^a
Weekly training hours (hr)	5.2 \pm 1.8	4.0 (4-8)	16.8 \pm 1.1	2.0 (16-18)	<0.001 ^a
Swimming experience (y)	8.8 \pm 1.6	3.0 (7.0 - 10.0)	8.0 \pm 0.84	2.0 (7.0 - 9.0)	0.260
History of shoulder pain (yes: no)	4:1		4:1		1.0

^a Significant difference between groups ($p < 0.05$).

standard deviation (SD) as all data presented a normal distribution (Shapiro-Wilk's test). Paired student t-test was used to assess within-group differences between pre- and post-measurements and independent sample t-tests were used to assess between-group differences. Differences were considered as significant when p values were ≤ 0.05 . Also, Cohen's d effect size (ES) was calculated to determine the magnitude of any difference between measurements.²³ The following ES values were considered: > 0.8 (large), between 0.5 and 0.79 (medium), between 0.49 and 0.20 (small), and < 0.2 (trivial). Finally, whether the results exceeded or not the measurement error (MDC) was also used to analyze differences. Given the small sample size ($n = 10$), results were presented in scatterplots to examine data distribution.

RESULTS

No differences were found between groups for age, sex, height, years of swim, and history of shoulder pain (Table 2). The high-level group reported greater swim-training volume ($p < 0.001$), hours of training ($p < 0.001$), training sessions ($p < 0.001$), and less body mass ($p = 0.009$) than the low-level group.

BASELINE DIFFERENCES BETWEEN GROUPS

Table 3 shows baseline differences of the outcome measures. University swimmers presented a lower baseline torque than national counterparts for external rotators (dominant side: $p = .007$; $d = 2.50$ and nondominant side: $p = 0.006$; $d = 2.55$) and internal rotators (dominant side: $p = 0.011$; $d = 2.12$ and nondominant side: $p = 0.014$; $d = 2.42$). There was no significant difference between groups for ER ROM and ER: IR ratio. Individual analysis showed that 80% and 100% of national swimmers had higher baseline rotator torque than university counterparts in dominant and nondominant side, respectively.

POST-SWIM SHOULDER EXTERNAL ROTATION ROM

Table 4 shows pre-post differences of the outcome measures. Figure 1 presents the results for shoulder ER ROM. University swimmers reported mean decrease in ER ROM with moderate ES for the dominant side ($p = 0.003$; change

= -8.4° ; $d = 0.74$). Although decreases in the nondominant side had large ES ($d = 1.05$; change = -6.4°), the difference was not significant ($p = .062$). The mean value of change on both sides exceeded the MDC. Individual analysis showed that all participants in this group reduced the ER ROM on both sides. Furthermore, 80% of the participants exceeded the MDC in the dominant side and 40% in the nondominant side.

In national swimmers, no significant pre-post differences were found on either side. Despite this, the ES was large for the dominant side ($d = 0.95$) and moderate for the nondominant side ($d = 0.43$). The mean value of change on the dominant side only exceeded the SEM, whereas, on the nondominant side, did not exceed the measurement error. Individual analysis showed that all participants reduced ER ROM on the dominant side and 80% on the nondominant side. Furthermore, 20% of the participants exceeded the MDC on both sides. There was no significant difference between groups.

POST SWIM SHOULDER ROTATION ISOMETRIC TORQUE

Figure 2 presents the results for shoulder rotator peak torque and shoulder ER:IR ratio. Regarding internal rotator torque, university swimmers reported a significant mean decrease with large ES for the dominant side ($p = 0.024$; change = 21.5%; $d = 1.66$). Although the decreases in the nondominant side had large ES (change = 15.1%; $d = 0.83$) the difference was not significant ($p = 0.108$). On both sides, the mean value of change exceeded the MDC. Individual analysis showed torque reductions in all participants in the dominant side and 80% in the nondominant side. Furthermore, 60% of the participants exceeded the MDC values in both sides. National swimmers had significant decreases with large ES for the dominant side ($p = 0.002$; change = 13.9%; $d = 0.91$) and moderate ES for the nondominant side ($p = 0.001$; change = 10.7%; $d = 0.61$). The mean value of change exceeded the MDC in the nondominant side and only the SEM in the dominant side. Individual analysis showed torque reductions in all participants in both sides. Furthermore, 20% of the participants exceeded the MDC in the dominant side and 80% in the nondominant side.

For external rotator torque, university swimmers reported a significant mean decrease with large ES for the

Table 3. Baseline difference between groups for shoulder external rotation range of motion and rotation isometric peak torque normalized to body weight.

Test		University swimmers	National swimmers	Mean difference	p Value	Effect size
External Rotation ROM, °	D	105.3 ± 10.9	100.3 ± 3.3	5.00	0.376	0.70
	ND	97.4 ± 5.6	98.2 ± 4.0	0.80	0.973	0.17
External rotator torque, Nm/kg	D	0.43 ± 0.05	0.53 ± 0.03	0.10	0.007 ^a	2.50
	ND	0.39 ± 0.05	0.53 ± 0.06	0.14	0.006 ^a	2.55
Internal rotator torque, Nm/kg	D	0.41 ± 0.08	0.59 ± 0.09	0.18	0.011 ^a	2.12
	ND	0.40 ± 0.06	0.63 ± 0.13	0.24	0.014 ^a	2.42
ER: IR ratio	D	1.08 ± 0.11	0.92 ± 0.14	0.16	0.081	1.28
	ND	0.97 ± 0.12	0.85 ± 0.12	0.12	0.167	1.00

D= dominant shoulder, ND= non-dominant shoulder. ^a Significant difference between groups (p < 0.05).

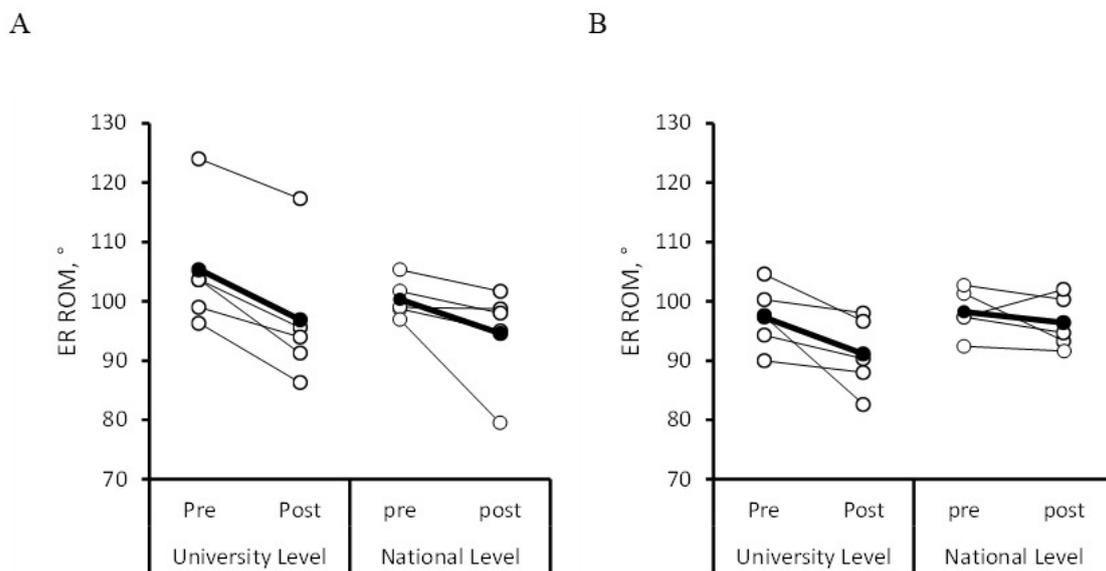


Figure 1. Scatterplots showing preswim and postswim changes in shoulder ER ROM for university and national swimmers.

A, dominant shoulder. B, nondominant shoulder. The bold lines indicate the mean value.

dominant side (p = 0.004; change = 17.2%: d = 1.28). Although reductions in the nondominant side had large ES (change = 9.0%: d = 1.14), the difference was not significant (p = 0.075). On both sides, the mean value exceeded the MDC. Individual analysis showed torque reductions in all participants in the dominant side and 80% on the nondominant side. Furthermore, 80% of the participants exceeded the MDC in the dominant side and 60% on the nondominant side. National swimmers had no significant differences in the dominant (p = 0.103; change = 3.7%: d = 0.50) and nondominant sides (p = 0.145; change = 9.1%: d = 0.96). On the dominant side, the mean value of change did not exceed the measurement error, and on the nondominant side, it exceeded the MDC. Individual analysis showed torque reductions in 80% of the participants on both sides. Furthermore, none of the participants exceeded the MDC in the dominant side and 60% in the nondominant side.

There was no significant difference between groups for internal rotator torque (both sides) and for nondominant side external rotator torque. However, external rotator torque of the dominant side was significantly lower in university swimmers compared to national counterparts (p = 0.003; d = 1.18).

SHOULDER ER: IR RATIO

University swimmers reported no significant differences between sides. Individual analysis showed increases in 80% of the participants in the dominant side and 60% in the nondominant. National swimmers reported a significant increase in the dominant side with large ES (p = 0.004; d = 0.80) but no differences in the nondominant side (p = 0.311). Individual analysis showed ratio increases in all participants in the dominant side and 80% in the nondominant.

Table 4. Mean Results from Preswim and Postswim of High-Intensity Training Sessions for Rotation Range of Motion and Isometric Peak Torque Normalized to Body Weight.

Test	Side	Preswim	Postswim	Mean difference	Mean % change	Within group		Between groups	
						p-value	Effect size	p-value	Effect size
University swimmers									
External rotation ROM, °	D	105.3 ± 10.9	96.9 ± 11.9	-8.4	-8.1 ± 3.0	0.003 ^a	0.74	0.444	0.35
	ND	97.4 ± 5.6	91.1 ± 6.3	-6.3	-6.4 ± 5.5	0.062	1.05	0.200	0.85
External rotator torque, Nm/kg	D	0.43 ± 0.05	0.36 ± 0.04	-0.07	-17.2 ± 6.0	0.004 ^a	1.28	0.003 ^b	1.18
	ND	0.39 ± 0.05	0.35 ± 0.04	-0.04	-9.0 ± 8.8	0.075	1.14	0.914	0.19
Internal rotator torque, Nm/kg	D	0.41 ± 0.08	0.32 ± 0.06	-0.09	-21.5 ± 9.4	0.024 ^a	1.66	0.160	0.13
	ND	0.40 ± 0.06	0.35 ± 0.03	-0.05	-15.1 ± 18.1	0.108	0.83	0.615	0.33
ER: IR ratio	D	1.08 ± 0.11	1.14 ± 0.11	+0.06	+6.3 ± 10.8	0.273	0.57	0.329	0.41
	ND	0.97 ± 0.12	0.99 ± 0.06	+0.03	+3.9 ± 11.3	0.600	0.12	0.763	0.18
National swimmers									
External rotation ROM, °	D	100.3 ± 3.3	94.6 ± 4.5	-5.7	-5.7 ± 6.9	.127	0.95	NA	NA
	ND	98.2 ± 4.0	96.4 ± 4.5	-1.8	-1.9 ± 4.6	.421	0.43	NA	NA
External rotator torque, Nm/kg	D	0.53 ± 0.03	0.51 ± 0.05	-0.02	-3.7 ± 4.0	.103	0.50	NA	NA
	ND	0.53 ± 0.06	0.48 ± 0.06	-0.05	-9.1 ± 9.6	.145	0.96	NA	NA
Internal rotator torque, Nm/kg	D	0.59 ± 0.09	0.51 ± 0.09	-0.08	-13.9 ± 4.0	.002 ^a	0.91	NA	NA
	ND	0.63 ± 0.13	0.55 ± 0.14	-0.08	-10.7 ± 5.1	.001 ^a	0.61	NA	NA
ER: IR ratio	D	0.92 ± 0.14	1.03 ± 0.13	+0.11	+12.0 ± 5.2	.004 ^a	0.80	NA	NA
	ND	0.85 ± 0.12	0.90 ± 0.15	+0.05	+6.2 ± 11.9	.311	0.35	NA	NA

Abbreviation: NA, not applicable, D=dominant, ND= non dominant

^a Significant difference within group (p < 0.05).^b Significant difference between groups (p < 0.05).

SESSION-RPE

University swimmers reported an RPE average of 6.4 ± 1.5 (min-max = 5-9), whereas national counterparts an average of 8.2 ± 1.1 (min-max = 7-9). Considering that both groups performed a 60 minute session, sRPE^h average was 384 ± 91 AU (min-max = 300 – 540 AU) for university swimmers and 492 ± 65.7 AU (min-max = 420 – 540 AU) for national counterparts. The difference between groups was not significant ($p = 0.064$). Individual analysis showed that 80% of national swimmers reported higher RPE and sRPE^h than university. Regarding sRPE^{km}, university swimmers reported an average of 12.8 ± 3.0 AU (min-max = 10 – 18 AU) and national swimmers an average of 24.6 ± 3.3 AU (min-max = 21 -27 AU). In this case, the difference was significant with large ES ($p < 0.001$; $d = 3.75$). Furthermore, all national swimmers reported higher sRPE^{km} than university counterparts.

DISCUSSION

The current study explored the relationship between training loads, physical qualities of the shoulder, and competitive level in swimmers. Due to the small sample size, the results were analyzed by the level of significance (p-value), magnitude of the difference (ES) and whether changes exceeded or not the measurement error (MDC). For the primary objective, the hypothesis was partially rejected. University swimmers had significantly less shoulder rotator torque at baseline. However, there was no baseline difference in shoulder ER ROM between groups. For the secondary objective, the hypothesis was also partially rejected. University swimmers experienced greater drops than national counterparts after a high-intensity swim-session. Despite this, only external rotator torque of the dominant side was significantly lower in university swimmers. The lack of significant differences in some variables might be explained by the small sample size. If groups are compared using ES and whether the results exceeded the measurement error or not, university swimmers showed more meaningful decreases in all the physical qualities after the training session. This is important as the ES and MDC are less affected by the sample size.²⁴

These results suggest that higher chronic loads and well-developed physical qualities (i.e., greater baseline rotator torque) seem to be a protective factor of postswim drops in shoulder physical qualities. Furthermore, that lower-level swimmers (i.e., lower load capacity) are possibly at higher risk of shoulder injury after swim-training than their higher-level counterparts. Since shoulder ER ROM and rotation isometric peak torque are potential risk factors for development of shoulder pain in swimmers,^{2,14} their monitoring before and after a training session, especially in lower-level swimmers, might have implications for injury risk. However, the results must be interpreted with caution due to the small sample size.

GROUP CHARACTERISTICS

Both groups were composed of male swimmers of a similar age and years of swimming experience. The main differences between groups were the amount of training they had been exposed to. As competitive level increases, so does the number of sessions and swim-training volume.³ In our study, national swimmers performed on average 37.0 ± 2.7 km per week, which is 5.4 times more than the university swimmers (average = 6.8 ± 1.8 km). Furthermore, national swimmers performed an average of 11.6 hours and 5.6 sessions of extra training per week compared to university counterparts. This shows that national swimmers were exposed to higher chronic loads.

SHOULDER ROTATION TORQUE

Baseline rotation torque was significantly higher in national swimmers than university counterparts with large effect sizes ($d = 2.12$ to 2.55). All national swimmers were stronger than university swimmers in the dominant side and 80% were in nondominant side. This is supported by Bae et al.⁴ who found that international swimmers had greater shoulder rotator force measured by isokinetic dynamometry than national swimmers. A later study⁵ reported that elite swimmers had also greater strength in the shoulder extensors, flexors, abductors, and adductors muscles than recreational counterparts measured by a hand-held dynamometer. The current results are in accordance with these studies showing that swimmers of a higher competitive level have greater baseline shoulder force, which might be explained by the greater chronic loads they are exposed to. This is important as greater upper body strength has been associated with swimming performance.²⁵⁻²⁷ Furthermore, athletes with lower shoulder ER strength have higher shoulder injury rates after an increase of training loads,⁹ which might have implication for injury risk.

For postswim changes, internal rotation torque was significantly decreased in both groups, particularly in the dominant arm. Despite this, university swimmers reported greater mean decreases as a percentage of body weight (15% to 21%) than national swimmers (10% to 13%). Furthermore, they had more clinically meaningful drops (large ES and values exceeding MDC) than national counterparts (moderate to large ES and only the nondominant side exceeding MDC). Importantly, a higher percentage of university swimmers had drops exceeding the MDC. Despite this, there was no significant difference between groups, which might be explained by the small sample size. Shoulder internal rotator muscles are constantly activated during the pull-through phase of the stroke²⁸ which can lead to muscle fatigue after a high-intensity swim-session.¹² Two cross-sectional studies have found that internal rotator force deficits in swimmers with shoulder pain.^{29,30} However, due to the cross-sectional design, of these studies, it is unclear whether the decreases in internal rotator force is the cause or consequence of shoulder pain.

External rotation torque was also decreased in both groups. Although none of the groups reported significant decreases in the nondominant side, the percentage of

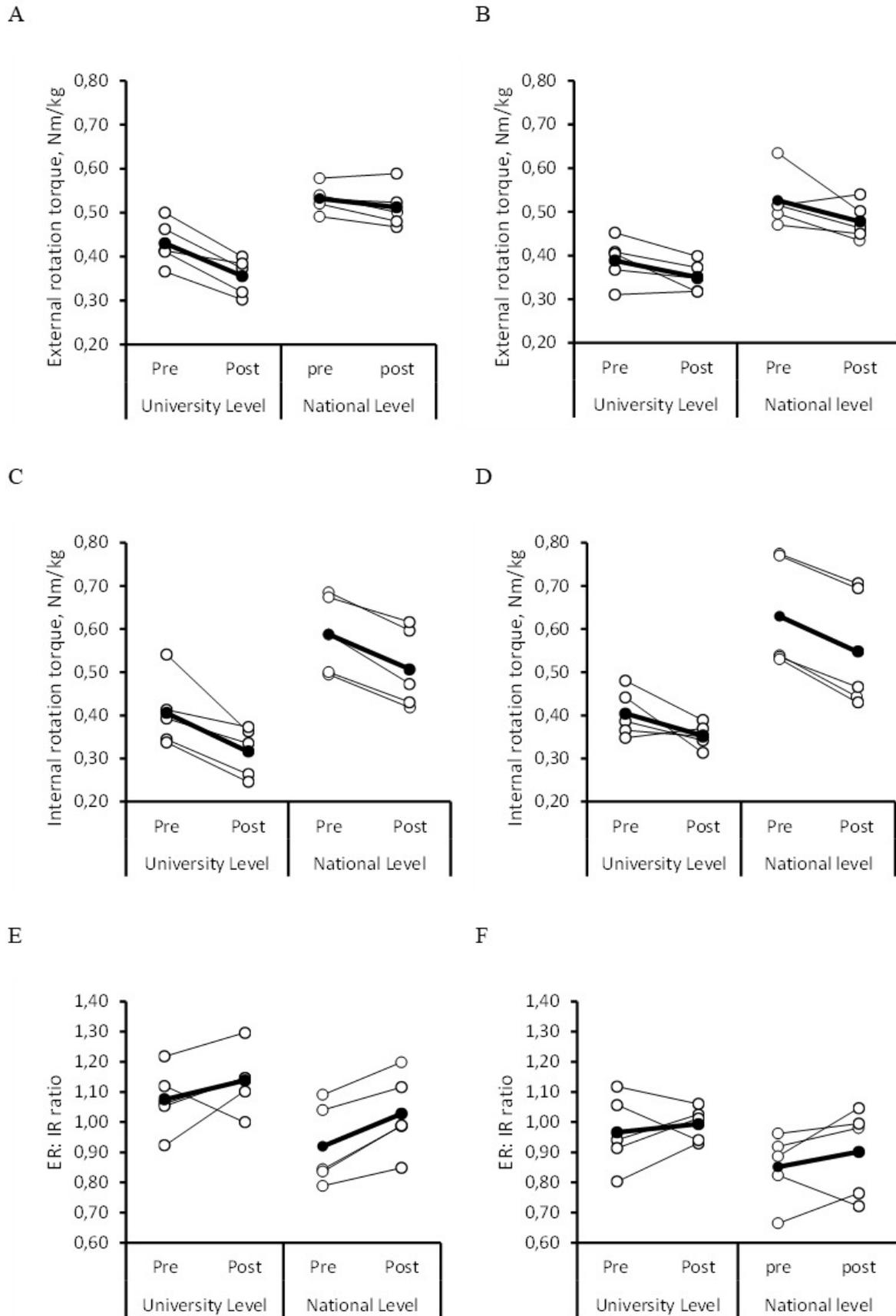


Figure 2. Scatterplots showing preswim and postswim scores in shoulder rotation torque for national and university swimmers.

A, External rotators in the dominant shoulder. B, External rotators in the nondominant shoulder. C, Internal rotators in the dominant shoulder. D, Internal rotators in the nondominant. E, ER:IR ratio in the dominant side. F, ER:IR ratio in the nondominant side. The bold lines indicate the mean value.

change (9.0% and 9.1%), large ES, and swimmers exceeding the MDC value (60%) was similar between groups. The main difference was seen on the dominant side. Reductions in university swimmers (17% of body weight) were significant, with large ES, and with 80% of participants exceeding the MDC. On the contrary, national swimmers reported non-significant drops (3.7% of body weight) with small ES and none of the swimmers exceeding the MDC. These results support why external rotation torque in the dominant side was the only variable significantly different between groups ($p = 0.003$; $d = 1.18$). Although shoulder external rotator muscles are less activated during swimming, their role is to control internal rotator forces.²⁸ Labriola et al.³¹ have indicated that decreased infraspinatus activity can lead to glenohumeral instability, which may result in functional impingement. A recent study showed acute decreases of shoulder external rotator torque after a high-intensity swim-session.¹² Interestingly, deficits in shoulder external rotator endurance rather than peak force have been reported as a potential risk factor for shoulder pain in swimmers in a cross-sectional³² and two prospective studies.^{7,33} Considering this, the authors recommend that future research explore postswim changes in shoulder external rotator endurance in this population.

Both groups increased their ER:IR ratio after a high-intensity swim-session, mainly in the dominant side. This means that proportionally, internal rotator torque was more affected than external rotator after a single training. Interestingly, national swimmers had greater increases in this ratio (6.2% to 12%) than university counterparts (3.9% to 6.3%). However, only the changes in the dominant side of national swimmers were significant. Contrary to the result of this study, Batalha et al.¹³ found no changes in shoulder ER:IR ratio after a swim-training session in competitive swimmers. This might be explained as the intensity of the session in the present study was high, whereas in Batalha et al.¹³ study was medium to low. Several authors have also investigated the changes in this ratio over a longer period,³⁴⁻³⁶ reporting reductions between 4% to 14% during a training period in young competitive swimmers. This shows that internal rotator torque increases proportionately more than external rotator during a training season.³⁵ Therefore, while a training season decreases the ER:IR ratio, a single swim-session increases it. However, it remains unclear whether this imbalance (increase or decrease) is related to shoulder injuries. Two cross-sectional studies have found no relationship between the ER:IR ratio and shoulder pain^{32,37} and one prospective study found a relationship³⁸ in competitive swimmers. This prospective³⁸ study found that low preseason shoulder ER:IR ratio was associated to an increase risk of injury during a season.

In summary, the results of this study showed that a high-intensity swim-session decreased shoulder rotator torque and increased the ER:IR ratio in both groups. However, university-level swimmers reported more meaningful changes. Lower-level swimmers have less tolerance to maintain loads during a high-intensity swim-session, which result in greater fatigue of shoulder rotator muscles. Possibly, lower

competitive level swimmers might be at higher risk of shoulder injury after a high-intensity swim-session.

SHOULDER ER ROM

Baseline shoulder ER ROM was similar between groups. Although one university swimmer presented more range in his dominant side, this was not consistent (Figure 1). To the authors knowledge, this is the first study to investigate baseline differences of shoulder ER ROM between levels of competition in swimmers. One study found that elite swimmers had more shoulder ER ROM (average of 15°) compared to a non-swimmer group.³⁹ The greater ROM found in swimmers was explained by the repetitive shoulder elevation during the stroke.³⁹ Although in the current study national swimmers were exposed to greater chronic loads (i.e., more repetitive shoulder elevation), the results showed no baseline difference between groups. This probably indicates that higher chronic loads in swimmers are more related to baseline differences in shoulder rotation force than ER ROM.

Regarding postswim changes, both groups reduced their shoulder ER ROM, predominantly in the dominant arm. However, the average decrease in university swimmers was greater (6.3° to 8.4°) and more meaningful (large ES and values exceeding MDC) than national counterparts (1.9° to 5.7° with small to large ES and values exceeding the SEM only). Despite this, only the changes in the dominant arm of university swimmers were significant. Individually, almost all swimmers reduced their ROM after the training session in both groups. Only one national swimmer increased the ROM in the nondominant side (Figure 1), which might explain the less significant result in this group. Interestingly, university swimmers presented a higher proportion of swimmers exceeding the MDC (40 to 80%) than national counterparts (20%). Despite this, the difference between groups was not significant. The results showed that, after a high-intensity swim-session, shoulder ER ROM decreased in both groups with more meaningful changes in low-level swimmers. Similarly, studies have also found reductions of ER ROM as a result of a single swim session¹⁰⁻¹² and the accumulation of loads during a week.⁴⁰ Importantly, deficits in shoulder ER ROM is a risk factor for shoulder pain in competitive swimmers.⁴¹ Since shoulder ER ROM is necessary during the mid-recovery phase when the arm is abducted at 90°, limitations of this movement may increase the probability of mechanical shoulder impingement.⁴¹

The findings are consistent with previous studies reporting decreases in shoulder ER ROM after a swim-training session in elite¹⁰ and national level swimmers.^{11,12} Interestingly, the study assessing the highest level of competition (i.e. elite) found the lowest drops in ER ROM (average = 3.4°),¹⁰ while the highest drops were found in the university group of the present study (average = 8.4° in the dominant side). This supports these results and suggests that higher competitive levels have less postswim reductions of shoulder ER ROM. However, it is difficult to make comparisons as the sessions are different in terms of intensity and distance. More studies with bigger sample sizes comparing

the effect of the same session in different groups might be necessary to confirm the current findings.

INTENSITY OF TRAINING SESSIONS

Despite national swimmers reporting less postswim changes in shoulder physical qualities, this group perceived the training session as harder. Both groups performed a one-hour session, but the national swimmers completed more volume (3 km) than university counterparts (2 km). To illustrate this, in the same period, national swimmers performed 33% more volume, which implies a higher intensity of the session and probably less recovery time throughout the session. This was expected as higher levels of competition perform greater swim-volumes and intensities. However, both training sessions were the hardest of the week which is proportional to the level of competition.

Comparing the $sRPE^h$, national swimmers perceived the session slightly harder, however, the differences between groups were not significant ($p = 0.064$; $d = 1.35$). Yet, if the $sRPE^{km}$ is compared, national swimmers perceived the session harder with significant differences and larger ES ($p < 0.000$; $d = 3.75$). The difference obtained between the two methods might be explained because $sRPE^{km}$ considers the volume instead of time. This shows that, in this study, $sRPE^{km}$ was more appropriate than $sRPE^h$ to compare internal training loads between groups. This is supported by Collette et al.²⁰ who recommended the use of $sRPE^{km}$ to monitor internal training loads as the influence of volume on the perceived exertion is greater than the training time in swimmers. Another explanation for the higher RPE found in national swimmers is the accumulation of training loads over the week. Although both groups were assessed the same day (Wednesday evening), at the testing day national swimmers had already performed five training sessions that week (average = 8.2 training sessions/week). Furthermore, they had done a morning session on the same day, while the university swimmers had only performed one or two sessions before the Wednesday session (average = 2.6 training sessions/week) and did not have a morning training on the testing day.

LIMITATIONS

This study presents limitations. First, although the study reported some findings (e.g., level of competition presenting more developed physical qualities and less postswim changes), it is underpowered (type II error). To be confident of the post-swim changes and differences between groups the study would have needed at least 16 participants per

group (version 3.1.9.2; G*Power). Because of the small sample size, the value of the analysis was increased in several ways.⁴² An homogeneous sample investigated a: males between 17 and 20 years old with similar swimming experience. Although this can decrease the between-subject variability and increase the power of the study, the results cannot be generalized to other populations. Repeated measures of the dependent variables (shoulder physical qualities) were also performed to decrease the variability and increase the number of measurements. Finally, reliable tools were used to measure the participants. Unreliable tools can increase variability and affect outcomes.⁴² Another limitation might be the structure of the swim-session. Although the swim-sessions were the hardest for each group, there might have been some differences in terms of structure which could have influenced the results. Further research should investigate a larger sample size including other levels of competition and development of physical qualities (e.g., elite group). Also, understanding whether postswim changes of shoulder physical qualities are related to the development of shoulder pain might be necessary.

CONCLUSIONS

University level swimmers have lower baseline shoulder rotator torque than their national level counterparts, which might be explained by the lower chronic loads they are exposed to. This might, to some extent, explain the greater postswim drops of shoulder physical qualities in this group. However, due to the small sample size, the results have to be interpreted with caution. The current results might have practical implications for recreational swimmers and triathletes (lower chronic loads). Since higher baseline shoulder rotator torque and chronic loads seem to be a protective factor of postswim drops in shoulder physical qualities, lower-level swimmers (i.e., lower load capacity) may be at higher risk of shoulder injury after swim-training than higher-level swimmers (more trained, thus greater load capacity). A shoulder strengthening program and monitoring of shoulder physical characteristics before and after a training session might be beneficial for lower-level swimmers. However, it is unknown whether the postswim impairments on shoulder force and ROM are associated with shoulder injury in this population.

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