Effect of two preventive exercise programs for swimmer's shoulder on the torque of shoulder rotator muscles in competitive swimmers: a randomized controlled trial

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Study Protocol

Trial design

A care provider and participants blinded, parallel, randomized controlled trial with three groups was completed from September 2022 to April 2023. This trial is reported according to the CONSORT 2010 checklist for randomized controlled trials. All procedures were approved by the Ethics Committee of the Polytechnic Institute of Coimbra (CEIPC 6/2022).

Participants

Swimmers were recruited from 2 national competitive teams in Portugal, affiliated with the Portuguese Swimming Federation during the 2022/2023 season. To be included in the sample, participants should be federated in the current season, aged between 16-35 years old, have a minimum of 5 years of experience in national competitions, and perform a minimum of 8 hours of weekly swimming training. Subjects who had performed at least 6 weeks of treatment such as physical therapy, injections, and medication, clinical situations such as a history of significant shoulder pain in the last 6 months, a history of traumatic shoulder injuries such as fractures, subluxations, cervical or thoracic conditions, previous shoulder surgeries, shoulder range of motion deficits, or neurological injuries, were excluded. All eligibility criteria were verified through an individual questionnaire before the sample selection. Each participant read and signed a written informed consent form based on the revised version of the 2013 Declaration of Helsinki. After being selected, all swimmers were weighed on a body composition scale Tanita RD-953, and measured using a stadiometer. The sample identity protection was preserved following the European Union General Data Protection Regulation – Regulation (EU) – 2016/679. This randomized controlled trial was conducted at the RoboCorp Laboratory at the Polytechnic Institute of Coimbra.

Intervention programs

Twice a week, over 12-weeks, the two intervention groups carried out a strength training program with the 5 open kinetic chain exercises most often reported in the literature to prevent swimmer's shoulder: internal rotation (IR) at 90°, external rotation (ER) at 90°, scapular punches, T's, and Y's (Table

1). The weight program group performed these 5 exercises with two weights Domyos with 1, 2, 3, 4, or 5 kg (Fig. 1), and the elastic band program group with an elastic band Bodytone Power Band with 10, 15, 20, 25, or 30 kg (Fig. 2). The load used to perform the programs with elastic bands and weights was previously assessed and adjusted for each swimmer, corresponding to 75% of one repetition maximum (1 RM). After 6 weeks of program execution, each swimmer carried out another 1 RM test assessment, to verify the possibility of a load instrument progression.

Participants performed 2 sets of 10 valid repetitions in each exercise. The repetitions were considered valid when the swimmer reached the target range of motion (ROM) previously described for each exercise (Table 1). The concentric and eccentric phases of each exercise were performed for 5 seconds. A Tabata timer mobile application controlled this time. One minute of rest was preserved between different exercises and sets.

Programs were supervised by a sport physiotherapist independent of the study. Each athlete received individualized monitoring with a regular exercise technique correction in all sessions. The first session was in person and the following sessions have online monitoring through WhatsApp Messenger or Zoom Video Communications, Inc.

Exercise	Weight program	Elastic band program
IR at 90º	Started in a supine position, 90° of shoulders ABD, 90° of ER and 90° of elbows FLX. Movement: 90° of shoulders IR.	Started in a SP, 90° of shoulders ABD, 90° of elbows FLX and hands at the same height as shoulders. Elastic band should be fixed at shoulder height. Movement: 90° of shoulders IR (5 s) and return to the start position (5 s).
ER at 90º	Started in a SP, 90° of shoulders ABD, 90° of elbows FLX and hands at the same height as shoulders. Movement: 90° of shoulders ER (5 s) and return to the start position (5 s).	Started in a SP, 90° of shoulders ABD, 90° of elbows FLX and hands at the same height as shoulders. Elastic band should be fixed at shoulder height. Movement: 90° of shoulders ER (5 s) and return to the start position (5 s).
Scapular punches	Started in a SP, 90° of shoulders ABD, 90° of elbows FLX and hands at the same height as shoulders. Movement: Elbow EXT (5 s) and return to the start position (5 s).	Started in a SP, 90° of shoulders ABD, 90° of elbows FLX and hands at the same height as shoulders. Elastic band should be fixed at shoulder height. Movement: Elbow EXT (5 s) and return to the start position (5 s).
T’s	Started in a SP, 90° of shoulders FLX and maximum elbows EXT. Movement: 90° of shoulders HABD (5 s) and return to the start position (5 s).	Started in a SP, 90° of shoulders FLX and maximum elbows EXT. Elastic band should be fixed at shoulder height. Movement: 90° of shoulders HABD (5 s) and return to the start position (5 s).
Y´s	Started in a SP, 90° of shoulders FLX and maximum elbows EXT. Movement: 90° of shoulders HABD and maximum shoulders FLX (5 s) and return to the start position (5 s).	Started in a SP, 90° of shoulders FLX and maximum elbows EXT. Elastic band should be fixed at shoulder height. Movement: 90° of shoulders HABD and maximum shoulders FLX (5 s) and return to the start position (5 s).

Table 2.
Description of 5 exercises that constitute the weight and elastic band programs

SP – standing position; s – seconds; ABD – abduction; ER – external rotation; IR – internal rotation; FLX – flexion; EXT –extension; HABD – horizontal abduction.

Fig. 1. Illustration of the 5 exercises included in the weight program: A) IR at 90°, B) ER at 90°, C) Scapular punches, D) T's, E) Y's.

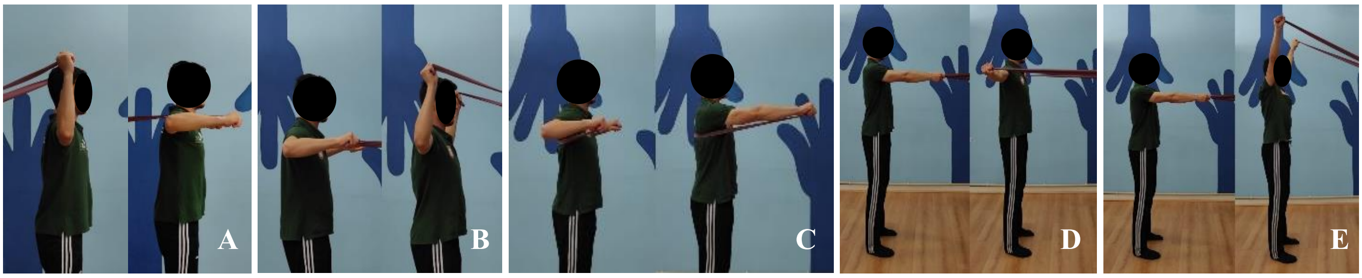

Fig. 2. Illustration of the 5 exercises included in the elastic band program: A) IR at 90°, B) ER at 90°, C) Scapular punches, D) T's, E) Y's.

Control group

The control group performed a sham intervention, twice a week, for 12-weeks. This intervention consisted of 2 sets of 10 repetitions of 5 shoulder mobility exercises, without preventive aim, normally carried out in warm-up before training: shoulder maximum flexion and extension, horizontal abduction and adduction starting from 90º of shoulder abduction, maximum IR and ER starting from 90º of shoulder abduction, circumduction of the shoulder in a clockwise direction and circumduction of the shoulder in a counterclockwise direction. There was no progression after 6-weeks of this sham intervention. The coach of the respective team checked the execution of the exercises, but there was no individualized monitoring with a regular exercise technique correction by a physiotherapist.

Outcomes and testing procedures

Before (T0) and after 12-weeks (T1) of interventions and control procedures, concentric and eccentric peak torque (PT) of IR and ER of the dominant and non-dominant shoulder was performed through an isokinetic dynamometer Biodex System 3 (Biodex Medical Systems, New York), at 60°/s, 120°/s and 180°/s.

Previously to strength evaluations, each swimmer did a 10-minute warm-up of a general upper limb joint mobilization. The isokinetic dynamometer assessment was carried out with the swimmer in the supine position. Half of the swimmers started the assessment with the dominant shoulder, and the other half started with the non-dominant shoulder. Previously, this order was randomized for each swimmer. The upper extremity was positioned with the shoulder abducted to 90° and the elbow flexed to 90° so that the dynamometer's axis was aligned with the longitudinal axis of the humerus. The athlete's trunk and evaluated arm were stabilized using velcro straps to avoid compensatory movements (Fig. 3). Gravity correction was not used for this testing position because the ER and IR shoulder muscles moved with and against gravity as they applied force. Strength was tested through 145° of range of motion (ROM), between 80° of ER and 65° of IR, to obtain the PT variation in the maximum rotational ROM available. The tests started every time with the shoulder in 80° of ER. The concentric strength was tested first, followed by the eccentric strength test. The order of the angular velocity test was increased (60°/s-120°/s-180°/s) to preserve an ascending difficulty during the evaluations. A hard cushion deceleration control was selected to allow the subject the greatest availability of velocity attainment before deceleration. The procedure was explained to all athletes before the start of testing, with emphasis on exerting maximal effort within an individual's tolerance. After this, swimmers performed 3 submaximal trials to familiarize themselves with the ROM and the accommodating resistance of the dynamometer. Both concentric and eccentric tests at different velocities consisted of 5 maximal-effort reciprocal repetitions. Standardized verbal instructions and encouragement were given to all subjects. A minute rest period between different tests was preserved.

The PT was used to characterize the strength values of shoulder rotator muscles, defined as the maximum torque produced by the shoulder at any point of the ROM. To analyze shoulder rotator strength balance, the ER:IR ratio was calculated – the quotient between PT values of the ER:IR multiplied by 100. For this investigation, the conventional concentric ER : concentric IR ratio and functional eccentric ER : concentric IR were calculated.

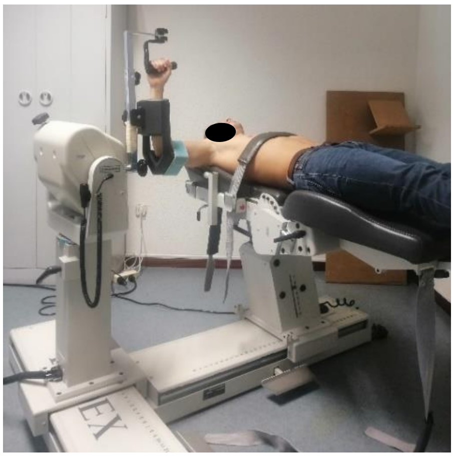

Fig. 3. Subject position and stabilizing during the isokinetic dynamometer strength assessment.

Sample size

The G*power software (Franz Faul, Edgar Erdfelder, Axel Buchner, Universitat Kiel, Kiel, Germany, version 3.1.9.4) was used to calculate the sample size, considering an alpha level of 0.01, a power of 0.99, and an effect size (Cohen's d) of 2.81 based in a similar previous study. Thus, a minimum of 24 swimmers – 8 for different groups – was necessary.

Randomisation and blinding

An initial screen survey was carried out on the two swimming teams before the sample selection. After the application of eligibility criteria, the eligible swimmers were divided into a weight program group, an elastic band program group, or a control group. The allocation to each group was performed through stratified randomization according to the team, sex, and main swimming style. This design was used to equate the possible effects of these three variables in results and was prepared with a computer random number generator by a member of the research team. Then, all swimmers carried out the T0 assessment moment through the isokinetic dynamometer. To minimize fatigue bias during the assessments, half of the swimmers started the evaluation with the dominant shoulder, and the other half started with the non-dominant shoulder. Previously, this order was randomized for each swimmer. After T0 moment, for 12-weeks the two experimental interventions were applied and supervised by a blinded sports physiotherapist external to the study, without knowledge of the previous procedures and the study objectives. It only explains in detail the interventions and the load that should be used by each athlete considering the 1RM test previously performed by a member of the research team. The participants were unaware of the existence of other sample groups. At the end of the 12-weeks, all swimmers who completed the proposed interventions carried out the T1 strength assessment through the isokinetic dynamometer. All T0 assessment procedures were maintained in T1 moment.

Statistical Analysis Plan

The data was previously filtered (smoothing option) and windowed at 95% of test velocity. Data analysis was performed using the Acqknowledge 4.1 software. The mean and standard deviation (SD) of the PT assessments in the 5 repetitions of different muscles (IR and ER), actions (concentric and eccentric), and angular velocities (60º/s, 120º/s, and 180º/s) for both sides were calculated. Subsequently, the conventional concentric ER : concentric IR ratio and the functional eccentric ER : concentric IR ratio were verified for these three angular velocities.

All statistical analysis was carried out using IBM SPSS Statistics 27 software. Mean and SD were used for sample characterization. The Shapiro-Wilk test was used to verify the normality of the sample distribution. The homogeneity of variance between the three groups was verified for the sample characterization variables and the main outcome at T0, through the One-Way ANOVA or the Kruskal-Wallis tests. After this, an inter-group analysis in T0 and T1 and an intra-group analysis between T0 and T1 was made for dominant and non-dominant shoulders. For an inter-group analysis, the One-Way ANOVA or the Kruskal-Wallis tests were applied to compare differences between the three groups in T0 and T1. For an intra-group analysis, the Paired Sample T-test or the Wilcoxon test was applied to compare differences in each group between T0 and T1. A p-value ≤ 0.05 was considered as the level of significance for each difference in PT and ER:IR ratios.