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PREVENTION & REHABILITATION: RANDOMIZED PROSPECTIVE STUDY

The effects of preventive rubber band training on shoulder joint imbalance and throwing performance in handball players: A randomized and prospective study

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A B S T R A C T

Objectives: To investigate the effects of a strength training program (STP) using rubber band exercises.
Methods: Twenty-five athletes were divided into two groups: muscular imbalance in the dominant (D) and in the non-dominant (ND) upper limbs. Each group was subdivided into experimental and control groups. Experimental groups performed eighteen sessions of STP. Athletes were submitted to ball throwing and isokinetic strength tests to assess the muscular strength of the shoulder rotator muscles and conventional and functional balance ratios.
Results: STP improved external rotator peak torque (18.0 ± 0.8 to 21.3 ± 1.0 Nm, $p < 0.01$) and total work (29.3 ± 0.9 to 34.5 ± 1.5 J, $p < 0.01$) in the D experimental group, while only total work (34.8 ± 2.5 to 37.6 ± 3.1 J, $p < 0.03$) improved in the D control group. The ND experimental group also presented significant improvement in external rotator peak torque (18.8 ± 0.8 to 21.1 ± 1.3 Nm, $p < 0.01$) and total work values (29.0 ± 1.4 to 34.6 to 1.6 J, $p < 0.01$) while there was no strength improvement in the ND control group. The ND experimental group showed an improvement in conventional (61.5 ± 3.5 to 72.7 ± 3.0%, $p = 0.03$) and functional (1.0 ± 0.1 to 1.6 ± 0.08, $p < 0.01$) ratios. STP did not improve the conventional ratio in the D experimental group. However, STP produced a large effect size. The D experimental group presented an improvement in ball velocity (49.0 ± 2.4 to 52.5 ± 2.2 km/h, $p = 0.04$) in standing position throwing.
Conclusions: STP improves muscular strength of external rotator muscles and muscular balance.
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1. Introduction

Arm throwing sports, such as handball, require an adequate rotator muscle strength balance between agonist and antagonist muscle groups in order to maintain the stability of the shoulder joint (Edouard et al., 2011, 2013; Ellenbecker and Davies, 2000).

The external rotator-to-internal rotator (ERconc/IRconc) concentric peak torque ratio is notable for its use in quantifying muscular imbalances (Andrade et al., 2013a, 2013b; Fleury et al., 2011). However, the ERconc/IRconc ratio, also known as the conventional strength balance ratio, does not include the eccentric contraction component that is involved in the shoulder throwing action, and so does not fully reflect muscle function during muscular activity. Therefore, the functional strength balance ratio (external rotator peak torque in eccentric action/internal rotator peak torque in concentric action, ERecc/IRcon) is also included in the evaluation of shoulder balance (Andrade et al., 2012; Niederbracht et al., 2008; Stickley et al., 2008).

As a result of extreme and repetitive throwing motion, the activated internal rotator (IR) muscles have been found to significantly increase in strength (Batalha et al., 2014). However, external rotator (ER) muscle strength does not increase proportionally to the strengthening of the IR muscles (Andrade et al., 2012, 2013a, 2013b; Batalha et al., 2014; Chandler et al., 1992; Niederbracht et al., 2008; Stickley et al., 2008). These adaptations cause a shoulder rotator

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muscle imbalance which has been associated with an increased risk of shoulder injuries (Stickley et al., 2008; Batalha et al., 2014; Byram et al., 2010). One possible and very useful method of assessing and managing muscular imbalance is an isokinetic device. Forthomme et al. (2013) conducted a prospective study aimed at identifying the most significant intrinsic risk factors for shoulder pain by measuring strength developed by shoulder rotator muscles and carrying out different morphostatic assessments. The authors concluded that the isokinetic strength of the IR and ER shoulder muscles appears to be the most important variable in identifying risk factors for shoulder pain.

To correct a muscular imbalance, therefore, a structured approach directed at the ER muscles is required (Bahr and Krosshaug 2005). Previous studies have demonstrated a significant improvement in isokinetic peak torque as a consequence of different types of strength exercise (Mascarin et al., 2016; Niederbracht et al., 2008; Treiber et al., 1998). One approach that overhead athletes commonly use to assist in restoring muscular balance is to include ER rubber band resistance exercises in their training (Mascarin et al., 2016; Niederbracht et al., 2008).

Despite the importance of shoulder strength balance for injury prevention, some coaches believe that ER strengthening programs directed at correcting the imbalance can actually harm performance. Studies have also shown a significant negative correlation between ball throwing velocity and rotator cuff strength balance (Cohen et al., 1994; Forthomme et al., 2015). Although a significant correlation does not indicate a causal effect, it is possible that a low ratio, which is associated with ER muscle weakness, may be beneficial for sport performance, as it is associated with a high ball velocity.

This study aimed to assess the effects on muscular strength, shoulder rotator muscle imbalance and ball throwing velocity of a strength training program (STP), using rubber band resistance exercises directed at the ER muscles, in order to evaluate (using an isokinetic dynamometer) the effectiveness of this approach.

2. Methods

2.1. Recruitment and subjects

Initially, seventy-six young female handball players from the *Olympic Center of Training and Research* (Sao Paulo - Brazil) were evaluated between March 2012 and December 2013. Handball athletes, from all positions, were recruited from the *Olympic Center of Training and Research Team*. The recruitment was carried out through advertisements placed in local newspapers. The inclusion criteria were: female handball athletes who had trained three times per week for three hours per session for at least the last competitive season, and who presented with shoulder strength imbalance with ER muscles weakness. Participants were excluded on the basis of shoulder pain, joint instability, range of motion limitation, previous injury, and/or surgery on the upper extremity over the preceding 12 months. From the 76 athletes initially evaluated, twenty-five were enrolled in the study. These athletes were diagnosed with ER weakness and consequent muscular strength imbalance of the shoulder rotator muscles, with a conventional strength balance ratio (ERcon/IRcon) lower than the recommended values of 0.66 (Ellenbecker and Davies, 2000) and/or a functional strength balance ratio (ERecc/IRcon) lower than 1.60 (Noffal, 2003). Fifty-one athletes were therefore excluded from the study. Fifteen athletes presented ER weakness in the dominant (D) limb and ten athletes presented ER weakness in the non-dominant (ND) limb. Athletes were divided into two groups according to which limb (D or ND) presented shoulder muscular strength imbalance. Limb dominance was determined by identifying the upper limb that the participant preferred to use to throw a ball. Athletes were then randomly assigned to the experimental or the control groups by drawing names from an opaque envelope. A non-participant study investigator prepared the envelopes and held the draw. A flow diagram illustrating the progress of the athletes through the trial is presented in Fig. 1.

All tests and interventions were performed in the *Exercise Physiology Laboratory of the Universidade Federal de São Paulo*.

We chose to verify the STP effect in the D upper limb separate from the ND upper limb because the ND upper limb is less trained than the D, and this fact might have influenced the results (Kraemer et al., 1999). The participants were informed about the intent and procedures of the study. Each participant and/or their parents/guardians provided informed consent before participation. The signed consent form was approved by the *Human Research Ethics Committee of the University* (protocol number: 1053/10).

2.2. Experimental procedures

First, athletes completed a questionnaire (clinical status) and body mass and height were measured. Secondly, isokinetic shoulder strength tests were performed in order to measure shoulder IR and ER muscle strength and to calculate shoulder conventional and functional strength balance ratios. Thirdly, athletes performed a ball throwing velocity test within three days of isokinetic testing. The experimental group undertook a STP, using rubber band resistance exercises, before regular handball training; both groups (experimental and control) conducted the same regular training in court (three times per week for three hours per session) and the same conventional strength training (once per week for one hour per session). Within a six-week period, all athletes were re-tested for shoulder strength and ball velocity.

2.3. Isokinetic shoulder strength testing

At the start, athletes performed five-minute warm-up exercises (Liebenson et al., 2008). Following the warm-up, individuals randomly undertook concentric and eccentric isokinetic shoulder strength tests (Biodex Medical Systems Inc., Shirley, NY, USA) for D and ND upper limbs according to the protocol of Niederbracht et al. (2008). Briefly, athletes performed three sub-maximal trials to familiarize themselves and were then tested with five repetitions for concentric action at 60 and 240°/second and five repetitions for eccentric action at 240°/second separated by a one-minute rest. A velocity of 60°/second (Moncrief et al., 2002; Hibberd et al., 2012) was used to evaluate the concentric ER and IR peak torque (PT), total work (TW), and the conventional strength balance ratio; and a velocity of 240°/second was used to evaluate concentric and eccentric ER peak torque and the functional strength balance ratios.

All athletes were tested by a single evaluator who was trained and experienced in the use of isokinetic testing devices. Before testing, the dynamometer was calibrated. The same verbal encouragement was given to each individual throughout the test. Visual feedback from the computer screen was not permitted (Andrade et al., 2013a).

2.4. Ball velocity

Ball velocity (km/h) was measured by radar gun (Stalker Radar, USA). Radar height was adjusted according to the athlete's throwing arm height, and it was placed in front of the athlete and behind the goal. Athletes performed one type of throw, as fast as possible towards goal, seven meters from the goal, with the contralateral foot in front of the ipsilateral foot. All athletes threw five times and mean values were used for statistical analysis. The

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