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Comparative study

Do isometric, isotonic and/or isokinetic strength trainings produce different strength outcomes?

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Introduction: Several studies have been developed to determine which type of muscular action (isometric, isotonic and isokinetic) elicits more gains in functional strength and muscle mass. The comparisons between training outcomes are inconclusive due to lack of exercise standardization.
Objective: To compare muscle strength, mass, and functional performance in response to isometric, isotonic, and isokinetic contractions, when training loads (volume and intensity) are equated.
Method: Data were derived from a university community-recruited sample ($n = 31$ men).
Interventions: Untrained men were assigned to isotonic (IT), isometric (IM), or isokinetic (IK) group, and trained their dominant quadriceps muscle 3 sessions/week for 8 weeks with a dynamometer. Muscle strength was assessed using Cybex 6000 dynamometer; the triple-hop-distance test was used to assess functional performance, and dual energy x-ray absorptiometry to assess lean muscle mass.
Results: After training, muscle lean muscle mass increased in isometric (+3.1%, $p < 0.01$) and isotonic groups (+3.9%, $p < 0.01$); only the isokinetic group showed a significant improvement in the triple-hop-distance test (4.84%, $p < 0.01$).
Conclusion: Clinicians should consider isometric training as an alternative for isotonic training to gain muscle mass, and isokinetic training to improve functional performance of daily activities and/or sports.

1. Introduction

Muscle strength is dependent on pennation angle, fascicle length and muscle cross-sectional area (Malas et al., 2013). Considering that, it is timely to understand what type of action will optimize muscle strength.

Isokinetic muscle strengthening has been used with great success in rehabilitation of: anterior cruciate ligament reconstruction (Dauty et al., 2014), jumping capacity in athletes (Rouis et al., 2015), osteoarthritis (Coudeyre et al., 2016), and muscle weakness caused by Parkinson's disease (Kakinuma et al., 1998).

Isotonic exercises also have been widely used in sports and clinical settings. They are suggested to prevent sarcopenia and loss of muscle strength (Taaffe et al., 2014), and to be incorporated in early rehabilitation programs (Okoro et al., 2016) (Jørgensen et al., 2017).

Isometric exercises are another interesting way of improving muscle function. Such exercises have been used to treat patellar tendinopathy and to be incorporated in early rehabilitation of the knee, when the range of motion is limited by pain (van Ark et al., 2016). Previous studies reported significant strength gains (ranging from 20 to 35%) after 3–4 weeks of exercise training (Pucci et al., 2006; Del Balso and Cafarelli, 2007). In this context, it is of fundamental interest to identify which type of exercise produces the best structural and functional muscle adaptations.

The studies that have attempted to compare the effectiveness of isotonic and isokinetic training to enhance strength are contradictory (Kovaleski et al., 1995; Remaud et al., 2010; Chen et al., 2015). The lack of standardization of strength training intensity

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and volume may be partially responsible for the inconsistency of the outcomes. Kovaleski et al. (1995) found greater muscle torque increase in isotonic than in isokinetic exercises, while Chen et al. (2015) showed better results with isokinetic exercises. Remaud et al. (2010) found similar significant strength gains in both exercises; however, these discrepancies could be due to high speeds of isokinetic training (150 and 180°/s) and a relatively low isotonic training load (40% of maximal voluntary isometric torque at 70°); probably more pronounced changes could be observed with a more intense program.

Although the number of studies on different types of muscle contractions is relatively large, few have compared isometric to dynamic exercises (Folland et al., 2005; Malas et al., 2013). One limitation of isometric training is that the strength increases are specific to the angle used. To overcome this problem, strength-training series were proposed to be done at different joint angles (Folland et al., 2005); the authors found that isometric and dynamic exercises showed similar isokinetic strength gain, but the gains in isometric strength were significantly greater on the isometrically trained lower limb. However, the authors stated that a possible bias may be absolute load discrepancies, once the load used in the different contractions mode was not the same. Therefore, one aim of the study was to compare the changes in muscle torque and mass in response to isometric, isotonic or isokinetic training matched for equivalent volume and intensity.

Another goal of the current study was to find out if the possible strength gains resulting from these different types of training are effective to improve functionality (i.e. performing a task). Functional assessment of lower limbs has increased in recent years. Designed to replicate the demands of sport and exercise, functional tests can be used to determine an individual's readiness to return to play after injury or illness and to detect abnormal limb symmetry or weakness (Ostenberg et al., 1998).

We hypothesized that training with different muscle actions (i.e. isometric, isotonic or isokinetic) would elicit greater strength only for the action trained. We also expect that the performance of the triple hop distance test will present the great improvement in isotonic training group, since the muscle contraction is similar.

2. Method

2.1. Study participants

The participants were staff and students from Federal University of São Paulo (São Paulo, Brazil) recruited between January 2013 and December 2014. The inclusion criteria was to be physically active (weekly volume of exercise is shown in Table 1), between 18 and 30 years old, and who had not undertaken any specific lower limb strength training in the last 6 months. For weekly activity characterization, we inquired and assessed their asked about daily living and physical activities. Specifically, participants were involved once or twice a week, one hour per day, of aerobic physical activity, such as running or walking. Participants were instructed to maintain the level of physical activity during the experimental protocol. Participants were excluded if they presented any knee pain, instability, edema and limitation of range of motion, and/or previous injury or surgery in their lower limbs. Initially, 48 participants were evaluated. From this sample, 42 met all the inclusion criteria. Eleven participants withdrew from the study for personal reasons, and thirty-one concluded the study (see Fig. 1). The physical characteristics of the participants are summarised on Table 1. They were informed of the intent and procedures of the study, and signed a written consent before data collection. The study protocol was approved by the Human Research Ethics Committee University and is in accordance in Declaration of Helsinki; it was registered with Brazilian Registry of Clinical Trials (RBR-7dp6hs).

2.2. Experimental design

On the first visit to the laboratory, participants completed a questionnaire on their clinical status. Those who fulfilled the inclusion criteria were directed to anthropometric measures and strength tests. Muscle torque was assessed via isokinetic dynamometry (Cybex 6000, Ronkonkoma, NY), muscle lean mass were measured via dual-energy X-ray absorptiometry (DXA, software version 12.3, Lunar DPX, Madison, WI) and functional performance of lower limbs was measured with the triple-hop-distance test. Anthropometric measurements and strength tests were done in the same day. Lean muscle mass and triple-hop-distance test were measured/performed in another same day. The participants were instructed to maintain their physical fitness habits during the study period. The two days of tests were performed in the same week. Prior to the baseline tests, participants underwent a familiarization test. After the pre-tests, participants were assigned either to the isometric (IM; n = 15), isotonic (IT; n = 14), or isokinetic (IK; n = 13) group.

Participants were evenly distributed among the three groups according to maximum voluntary isometric torque at 70° (MVIT70°). Before allocating a new volunteer in one of the three groups, an average of maximum voluntary isometric torque was assessed and, according to the result of each group, the participant was allocated. This allocation strategy is known as stratified random sampling strategy and has been adopted previously (Remaud et al., 2010). We chose to carefully match the participants according to their level prior to training sessions to avoid differences in the baseline strength levels. Two or three days after the baseline testing the tree groups performed the strength sessions three times a week for eight weeks. Within two or three days upon completion of the eight-week training period, all participants were tested for anthropometric measures, strength and horizontal hop-test for lower limbs again. The participants were unaware of the nature of the strength training they would be doing; it was, therefore, a single-blinded study.

2.3. Participant positioning

Isometric, isotonic and isokinetic torque measurements were assessed dominant and non-dominant lower limbs were assessed.

Table 1
Physical characteristics of the participants included in the isometric (IM), isotonic (IT), and isokinetic (IK) groups.

Group	Age (years)	Body Mass (kg)	Height (cm)	$MVIT_{70°}$ (Nm)	Weekly activity (h)
IM (n = 11)	21.7 ± 2.8	72.1 ± 6.2	173.7 ± 6.0	231.9 ± 29.0	6.3 ± 3.2
IT (n = 10)	21.4 ± 2.9	73.3 ± 8.3	174.8 ± 7.4	228.8 ± 32.3	7.3 ± 3.3
IK (n = 10)	22.0 ± 3.4	73.2 ± 11.7	175.1 ± 4.4	230.5 ± 20.0	6.4 ± 3.1

Data are presented as mean ± SD. No statistical differences were found between groups for baseline age ($p = 0.94$), height ($p = 0.85$), body mass (0.94), $MVIT_{70°}$ ($p = 0.96$), weekly activity ($p = 0.63$).

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