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A case study of isokinetic training: is maximal effort enough to increase strength?

Um estudo de caso sobre treinamento isocinético: o esforço máximo é suficiente para o aumento de força?

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RESUMO | INTRODUÇÃO: Dinamômetro isocinético é um equipamento eletrônico e mecânico, capaz de medir o torque gerado por um determinado segmento, bem como a potência e estimar fadiga, observando-se a variação do torque ao longo tempo. Este dispositivo também controla a velocidade do movimento angular, seja ele gerado por uma contração excêntrica ou concêntrica. Este tipo de equipamento tem sido utilizado tanto para avaliação como para treinamento de força. **OBJETIVO:** Verificar o efeito do treinamento de força, realizado exclusivamente no dinamômetro isocinético, na capacidade de gerar torque isométrico. **MÉTODO:** 2 homens, sedentários, saudáveis com idade de 23 e 24 anos realizaram 16 sessões de treinamento de força (sempre em esforço máximo e no modo concêntrico utilizando-se um dinamômetro isocinético) para os músculos flexores da articulação do cotovelo do membro dominante. As sessões foram compostas por um treinamento de quatro séries de oito repetições em uma amplitude de movimento de 130°, com velocidade fixada em 45°/s. As avaliações de contração isométrica voluntária máxima (CIVM) a 90° de flexão da articulação do cotovelo foram realizadas na primeira, oitava e décima sexta sessão. Espessura dos músculos flexores da articulação do cotovelo também foi medida, com ultrassonografia, nas mesmas sessões em que o torque máximo isométrico foi medido. **RESULTADOS:** Não houve diferença significativa no ganho de torque tam pouco na espessura muscular, ao final do treinamento. **CONCLUSÃO:** Treinamento de força, exclusivamente realizado no modo concêntrico no dinamômetro isocinético não provocou aumento da capacidade de gerar força isométrica, tam pouco aumento da espessura muscular.

PALAVRAS-CHAVE: Dinamometria isocinética. Contração concêntrica. Treinamento de Força. Força Muscular.

ABSTRACT | INTRODUCTION: Isokinetic dynamometer is an electromechanical device that allows measuring the torque of a segment, as well as estimating power and fatigue by observing the variation of torque over time. This device also controls the speed of the angular movement, whether it is generated by an eccentric or concentric contraction. This equipment is utilized for both evaluation and strength training. **OBJECTIVE:** Verify the effects of strength training performed on an isokinetic dynamometer on the capacity to generate isometric torque. **METHOD:** Two healthy, sedentary men, aged 23 e 24 performed 16 strength training sessions (always at maximum effort) for elbow joint flexor muscles of the dominant limb. The sessions were composed by a training of four sets of eight repetitions in a range of movement of 130°, at 45°/s. The evaluations of maximal voluntary isometric contraction (MVIC) in a 90° of elbow flexion was realized in the first, eighth and sixteenth sessions. Thickness of the flexor muscles of the elbow joint was also measured with ultrasonography at the same sessions in which the maximum isometric torque was measured. **RESULTS:** There was no significant difference in torque gain or in muscle thickness at the end of the training protocol. **CONCLUSION:** Strength training, exclusively performed in the concentric mode on an isokinetic dynamometer did not caused an increase in the capacity to generate isometric torque and did not change muscle thickness.

KEYWORDS: Dynamometer. Isokinetic Contraction. Strength Training. Muscle Strength.

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Introduction

Dynamometry is a very important research area in biomechanicsfocused on measuring the forces present in the human movement[1]. The so-called isokinetic dynamometer is an electromechanical equipment that measures the torque produced by muscle contraction. It is able to measure the production of torque, muscle power, fatigue and torque variation over a given action[2,3,4]. Furthermore, this device controls the joint velocity, resulting in an isokinetic muscle contraction, meaning minimal acceleration and deceleration during the range of joint movement[5,6].

This methodology is widely used to evaluate muscle function, once it allows the muscles to generate maximum strength in all degrees in a range of movement, and offers accurate and reliable measures such as the ratio between flexor and extensor torque, sense of force, sense of position, which may be a useful tool to complement the diagnosis of musculoskeletal conditions, including assisting in decision making when a patient is ready to return to work or an athlete is ready to return to competition[3,4].

One of the muscular parameters that is obtainable from dynamometry is the torque ratio obtained from antagonistic muscles. This parameter is used as an indicator of imbalance and is more often used than it is the maximum torque, according with Campbell, Gleen (1982)[7]. This ratio has been analysed in several studies, especially in athletes during the pre-season[8].

Besides being used as an evaluation tool in rehabilitation and sports, the isokinetic dynamometer is also used for training, due to the possibility to control the velocity, torque generated, and the range of motion during every trial in a training session.

In rehabilitation, overload, velocity and range of motion are crucial parameters to be controlled and monitored, which make the dynamometer isokinetic very useful when an individualized protocol must be applied[9]. For example, Eyigor (2004) showed that osteoarthritis patients benefit from exercises performed exclusively in a dynamometer isokinetic by a significant increase in muscular strength and decrease in pain[10]. Athletes submitted to anterior cruciate ligament reconstruction also presented decreased pain scores and increased range of movement after strength training sessions in a dynamometer isokinetic[11].

Although there are several studies showing the benefits of strength training using isokinetic equipment for the lower limbs, only few studies focused on the upper limbs, making it difficult to standardize a training protocol for the upper limb. Hereupon, the purpose of the present study was investigate the effect of a strength training protocol using exclusively concentric elbow flexion movements performed in an isokinetic dynamometer.

Method

The study is in agreement with the Resolution n. 466/2012 of the National Health Council - Brazil and was approved by the São Judas Tadeu University Research Ethics Committee, registry n. 1.977.074. Volunteers received an informative text with detailed explanation about the experiment and procedures and signed a consent form.

This is a longitudinal study that involves a strength training protocol. Two healthy men who didn't attend any strength training in the last six months participated in the study. In table 1, it is shown the volunteers anthropometric characteristics.

Table 1. Anthropometric characteristics

	Age	Weight (kg)	Height (cm)
V1	24	85.3	1.72
V2	23	75.2	1.69

V1: volunteer one, V2: volunteer two

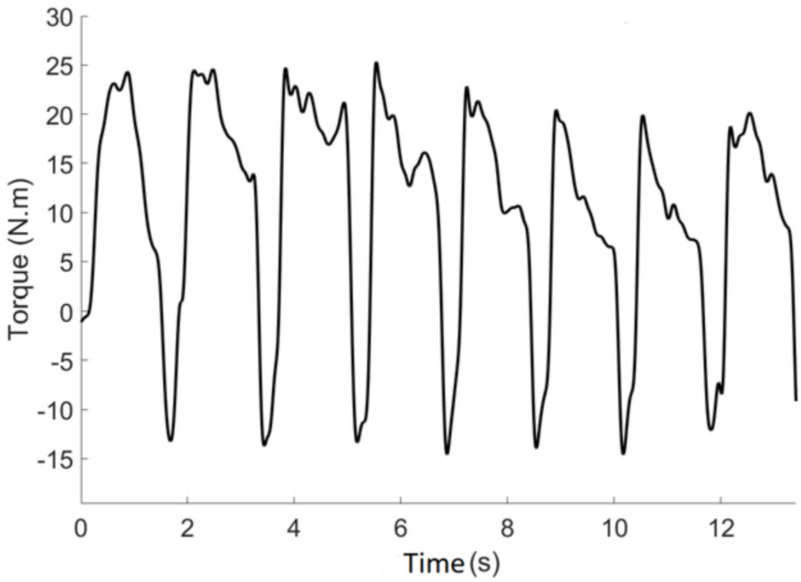
The volunteers attended the lab for a total of 16 training sessions. On the first session they had up thirty minutes to familiarize with the protocol. The training consisted of 16 strength training sessions for the flexor muscles of the elbow joint of the dominant limb. During the procedure, the participants sat comfortably in the isokinetic dynamometer chair (Biodex 3 – System), keeping the elbow joint of the dominant arm comfortably supported by an adjustable height support in order to maintain a shoulder joint positioned at 45o of flexion and abduction and the elbow joint aligned to the axis of the equipment. The thorax, pelvis and lower limb were fixed to the chair by belts in order to minimize undesired or compensatory movements. Figure 1 illustrates the position of the volunteer.

Figure 1. Positioning of the volunteer in the isokinetic dynamometer

Eight low-intensity elbow flexion movements at 130o of range and at the speedof 180o/s were used as warm up. In the first and in the eighth sessions, and at the end of the sixteenth session (last), the participants performed two tests of maximal voluntary isometric contraction (MVIC) with the elbow joint at 90o. Each MVIC trial had three seconds of duration and 30 seconds of interval between the trials. The highest value obtained in the tests was considered for the analysis.

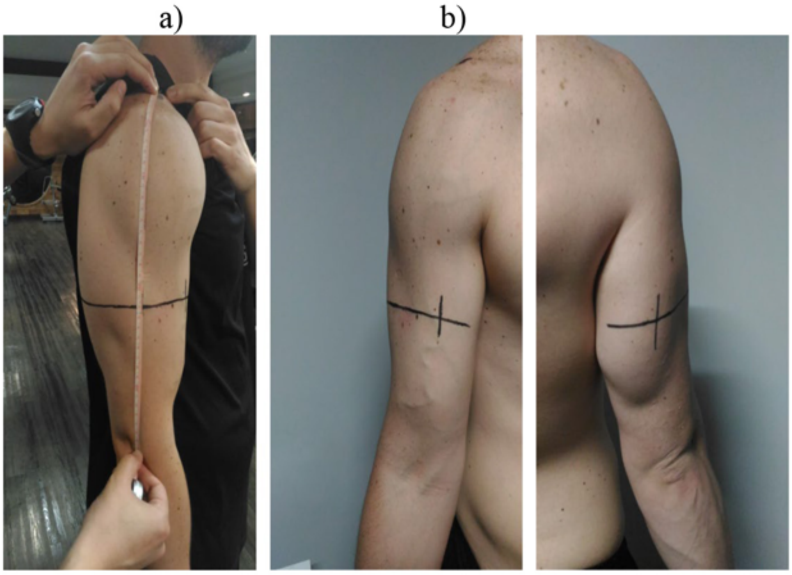
Right after warm up, the strength training protocol, adjusted in concentric operation mode, was performed in the isokinetic dynamometer. The training consisted in four sets of eight repetitions of elbow joint flexion (always at maximum effort) of the dominant limb, in a range of movement of 130°, with the velocity set at 45°/s. Between the sets there was a 60 seconds rest. A verbal command was standardized in order to encourage the participant to perform maximum effort during the movement. Figure 2 shows the torque generated during one training set.

Figure 2. Example of a training session showing the torque curve generated during the execution of a series of concentric movements at maximum effort



The thickness of the muscle was measured using ultrasound. A researcher trained in image exams and unrelated to the training sessions, performed all evaluations using a B-mode (Bodymetrix pro System, Intelametrix Inc., Livermore, Calif., USA) ultrasound. The thickness of the flexor muscles of the elbow joint was obtained on both sides. The determination of the anatomical region in which image acquisition was performed followed the methodology used by Schoenfeld et al (2015). For flexor elbow muscles, the length of the arm segment was initially measured, taking as reference the distance between the acromial process of the scapula and the lateral epicondyle of the humerus. The analyzed region corresponds to 60% of the segment length, starting from the acromion process (figure 3). The analysis was performed with the volunteers seated.

Figure 3. Markings in the arm segment where the ultrasound head was placed. (a) 60% of the length; (b) region of analysis of the elbow flexor muscles



The data collected with ultrasonography was performed in the following sequence: (i) application of the transmission gel (Mercur S.A. - Body Care, Santa Cruz do Sul, RS, Brazil) on the top of each analysed region; (ii) positioning of the probe of the linear type (5MHz) perpendicular to the direction of the muscular fibers, without pressing the skin. When the quality of the image was considered satisfactory, it was stored on the hard disk and the muscular thickness dimensions were obtained through the distance between the subcutaneous tissue/muscle interface and the muscle/bone interface, according to the protocol used by Abe et al. (2000). Three images were obtained, allowing the average of the three to be used for analysis. The values reported for each group corresponded to the calculation of the mean of these three images. An agreement value of 1 mm (mm) was stipulated between each image, that is, the thickness values of the three images showed no difference greater than 1 mm. These measures were performed in training sessions 1st, 8th and 16th.

Statistical Analysis

In order to compare the measured variables between series it was applied the methodology that includes the confidence interval to inference based on "Magnitude-Based Inference"[12].

To stablish the confidence interval, it was considered the statistical parameters of an earlier study involving strength training, in which the results of the isometric peak torque as well as the cross-sectional area of the trained muscles were presented[13].

Results

The calculated confidence interval (CI) is CI= 0.7 ± 0.5; 0.2 – 1.2, which means that in order to be established a significant difference for the peak torque, the obtained measure needs to at least 4.8% smaller or 28.86% higher than the mean obtained in the first session. For to muscular thickness, the values were set between 3.75% and 21.12%.

The training performed exclusively by doing concentric contractions using an isokinetic dynamometer during eight weeks (16 sessions) did not produce a significant increase in the strength, measured as peak torque and muscular thickness.

It is possible verify on table 2 that the volunteer 2 presents a decrease in peak torque produced during the MVIC performed in the eighth session, as well as in the sixteenth session if compared to of the first session.

Table 2. Peak torque obtained in the first session and the percentage of this values obtained in the 8th and 16th sessions

Session	1st (peak torque in N.m)	8th (% of 1st session)	16th (% of 1st session)
V1	69	+ 4.35	- 2.90
V2	60	- 25*	- 6.67*

*Significantly smaller than the lower limit of the confidence interval. V1 and V2, respectively, volunteer 1 and 2.

Table 3 shows the ultrasound measurements of muscle thickness. One can observe a significant decrease presented by volunteer 2, with values in the eighth and sixteenth sessions significantly lower than in the first session.

Table 3. Muscle thickness (mm) obtained in the first session and the percentage of this values obtained in the 8th and 16th sessions

Session	1st (muscle thickness in milimeters)	8th (% of 1st session)	16th (% of 1st session)
V1	36.4	+ 16.76	- 1.65
V2	42.1	- 12.59*	- 11.64*

*Significantly smaller than the lower limit of the confidence interval. V1 and V2, respectively, volunteer 1 and 2.

Discussion

The present study investigated the effect of a strength training protocol for the flexor muscles of the elbow joint, performed exclusively using isokinetic equipment. The measure was taken in three epochs; immediately before the strength training protocol, four weeks after starting, and immediately after the end of the training protocol. The strength training consists in a two-sessions a week (4 sets of 8 repetitions at 45°/s speed) along eight weeks, in a total of 16 sessions of training. All the sessions and evaluations were doneusing an isokinetic dynamometer. Volunteers have always made the most effort, whether in evaluations or during training. Data collected showed that none of the volunteers significantly increased isometric strength or muscular thickness. Therefore, our hypothesis has not been confirmed.

There are numerous studies showing contradiction to our results. Kelly et al. (2007), applied a protocol consisting in a concentric training over fifteen sessions performing knee joint extensions at 60°/s (3 sets of 8 repetitions) during 8 weeks. The protocol resulted in a 17,5% increased torque of the knee joint[14]. Colliander et al. (1991) showed an even greater gain in peak torque (37%), when volunteers trained at a speed of 60o/sand performed 4-5 sets of 6 repetitions, three times a week over twelve weeks[15]. Coyle (1981) also found a similar result, showing a 32% peak torque increase in eccentric training of the knee joint (5-6 sets of 6 reps at 60o/s, three times a week)[16]. Avila (2008) showed that there is a 10% increase in peak torque (knee extension) when 3 sets of 10 repetitions, during four weeks, twice a week are performed[17].

Despite the differencespresented in the literature regarding peak torque gain due to strength training performed in a isokinetic device, all the studies showed significant differences, which might be explained based on the methodological differences presented in the studies, mainly in relation to the number of training sessions. However, it is important to consider that in studies where the strength training protocol fails to increase strength, the authors are more likely to change the protocol and not to publish the initial data. This explains why there is no data in the literature pointing to inefficient training protocols. In the present study, we chose to present the data referring to a protocol that did not have the expected effects.

Another important issue to be considered is that there are not many studies in the literature investigating the effects of strength training (using isokinetic dynamometry) applied to the upper limbs, making it hard to compare our findings with the literature. When searching the literature in order to compare our data with others, we found two similar, but not exactly comparable, studies. Ellenbecker et al. (1988) compared the effect of isokinetic training (internal and external rotation of the shoulder joint) performed at different speeds, using the so called pyramidal module (60, 180, 210, 180 and 60°/s). They found a significant concentric and eccentric strength gains at all three velocities (60, 180, and 210°/sec)[18]. Ratamess et al. (2016) investigated the strength magnitude and endurance after 6 weeks of multiple-joint isokinetic resistance training. The main finding of the study was that six weeks of multiple-joint isokinetic resistance training increases dynamic maximal strength and muscle endurance in addition to maximal isokinetic strength capacity[19]. Although Ellenbecker and Ratamess applied different protocols, in both studies the isokinetic training increased strength.

Garnica (1986) compared a strength training protocol (4 sets of 5 reps; 4 weeks; 3 sessions a week) performed at 60°/s with the same protocol performed at 180°/s. The results showed significant increase in the extensor torque of the shoulder joint on both groups, with no difference between groups. This protocol is similar to ours, especially considering the slower speed; however, the results are quite different.Perhaps some of the twenty volunteers in this study did not increase their capacity to generate force, but the data was overshadowed by the variability of the group.Another issue to be considered is that, in our study, the training was performed dynamically, but the evaluations were performed in the isometric mode. In the Garnica's study, both training and evaluation were performed in dynamic mode[20].

Using isokinetic dynamometry equipment requires technique, care and attention. Patterson (1992) pointed an important aspect when carrying out this kind of study. According to the author, calibration, familiarization, body stabilization and position, torquemeter alignment, correction of the gravity force factor, verbal encouragement given to the participant, visual feedback and personal motivation, all those particular factors should be taken into account throughout the experiment[21]. Considering that there was not any bias on the adjustment of the dynamometer, volunteers' position, verbal incentive and visual feedback, one might argue that personal motivation may not have been enough and this could lead into the results of the present study.

Although the present study did not show anypeak torque increase after isokinetic training, the literature presents positive data regarding the use of isokinetic dynamometry to increase strength, especially regarding to athletes and orthopedic patients in rehabilitation[3,13,22,23].

More research is required, mainly to address the bias over the differences in studies involving isokinetic training applied for upper limbs.

Conclusion

The present case study involving two untrained volunteers showed that the strength training for upper limbs on isokinetic dynamometer at 45°/s was noteffective in increasing peak torque or muscle thickness.

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Author contributions

Batista IST participated in the writing and interpretation of the data. Silva VP participated in the data collection, study design conception, writing of the paper, statistical analysis of the data of the scientific article. Souza CC participated in the study design conception and data collection of the scientific article. Conceição RM participated in the analysis of data. Goethel MF participated in the statistical analysis, interpretation of the data and in the writing of scientific article. Ervilha UF participated in the study design conception, data interpretation and in the writing of the scientific article.

Competing Interests

No financial, legal or political competing interests with third parties (government, commercial, private foundation, etc.) were disclosed for any aspect of the submitted work (including but not limited to grants, data monitoring board, study design, manuscript preparation, statistical analysis, etc.).

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