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Effects of cryotherapy and microwave diathermy on the strength production capacity of elbow flexors in healthy men

Efeitos da crioterapia e da diatermia por micro-ondas sobre a capacidade de produção de força de flexores de cotovelo de homens saudáveis

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Abstract – Physiological effects of thermal changes in tissues might influence some physical properties of muscle fibers, such as strength. The aim of this study was to compare the effects of cryotherapy and microwave diathermy application on the strength production capacity of the elbow flexor muscles. Thirty male, healthy and sedentary subjects, with average age of 22.40 (±3.42) years, participated in this prospective study. Participants were submitted to assessment of isometric strength production capability by an adapted load cell. Half of volunteers received cryotherapy on the first day of application and microwave diathermy (MD) 48 hours later, whereas the other half was treated the other way around. Cryotherapy was applied up to the temperature of the biceps region reached 25ºC, and MD was applied up to 42ºC. Six peak strength reevaluations were made over 2 hours. There was significant increase in peak strength (PS) up to 15 minutes after cryotherapy, then there was a decrease in maximum isometric strength, however, statistically significant difference remained up to 1 hour and 30 minutes after cryotherapy. In MD, PS decreased significantly after application until 15 min. From this moment, PS returned close to the initial value, and in the last assessment, PS reduced again. Cryotherapy and MD differently interfered in isometric muscle strength production capacity of elbow flexors, while cooling generated increment, heating caused decline.

Key words: Cryotherapy; Diathermy; Muscle Strength; Thermotherapy.

Resumo – *Os efeitos fisiológicos das mudanças térmicas nos tecidos podem influenciar propriedades físicas das fibras musculares, como a força. O objetivo deste estudo foi comparar os efeitos da aplicação da crioterapia e da diatermia por micro-ondas (DMO) sobre a capacidade de produção de força dos músculos flexores de cotovelo. Participaram deste estudo prospectivo 30 voluntários do sexo masculino, saudáveis, não praticantes de atividade física, com valor médio de 22,40 (±3,42) anos de idade. Foram submetidos à avaliação da capacidade de produção de força isométrica, por meio de uma célula de carga adaptada. Metade dos voluntários recebeu no primeiro dia aplicação da crioterapia e no outro dia (48 horas depois) a DMO, e a outra metade dos sujeitos o inverso. A crioterapia foi aplicada até que a temperatura na região bicipital atingisse 25ºC e a DMO foi aplicada até que atingisse 42ºC. Seis reavaliações do PF foram feitas ao longo de 2 horas. Houve incremento significativo no pico de força (PF) até 15 minutos após a aplicação da crioterapia, a partir desse momento houve decréscimo da força isométrica máxima, no entanto, a diferença estatisticamente significativa esteve presente até 90 minutos depois. Na DMO, o PF reduziu significativamente até 15 min após a aplicação do recurso. A partir deste momento, o PF foi retornando próximo ao valor inicial. Na última avaliação, o PF reduziu novamente. A crioterapia e a DMO interferiram de maneira diferente na capacidade de produção de força muscular isométrica de flexores de cotovelo, enquanto o resfriamento gerou incremento, o aquecimento causou declínio.*

Palavras-chave: *Crioterapia; Diatermia; Força muscular; Termoterapia.*

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INTRODUCTION

The neuromuscular system may respond differently to thermal agents imposed on it. Physiologically, tissue cooling may influence some neuromuscular parameters[1], and there may be direct or indirect influence on the physical properties of muscle fibers such as strength[2]. They may also generate increased tissue stiffness, vasoconstriction, decreased cell metabolism rate, influence the production of cellular waste[1], inflammation, pain, muscle spasm[1,3], bleeding and / or swelling at the injury site[4], in nerve conduction velocity[1,3,5], in the ability to perform rapid movements, release of endorphins and break of the pain-spasm-pain cycle[1].

There is evidence that cooling the skin can give greater strength to adjacent muscles[6]. Similarly to cooling, heating also changes the physiologic effects of tissues, and MD is indicated in order to increase circulation, improve blood flow, improve ADM to decrease joint stiffness and increase the extensibility of collagen fibers and elasticity of soft tissues[7].

Heating by microwave uses 300 MHz to 300 GHz of frequency, from 1 mm to 1 m in wavelength to generate heat and other physiological changes in tissues[8]. These waves are more rapidly absorbed by the deep tissues with high water content and ions such as muscles and absorbed more slowly in fat and bone tissue[7].

The effect of temperature on muscle strength is a complex issue that involves the effects of cold[2,9,10,14] and heat in the contractile process[9,19,21]. The evaluation of muscle strength is essential to human performance. The precise knowledge of muscle strength level of an individual is important both for the evaluation of functional capacity and for appropriate exercise prescription[11]. Changes in muscle strength may both reflect the health status and predict performance for various sports.

The aim of this study was to compare the effects of application of cryotherapy and MD on isometric force production capacity of elbow flexors in healthy men not engaged in physical activity.

METHODOLOGICAL PROCEDURES

This prospective study of applied character was classified as quantitative and conducted in accordance with Resolution 466/12 of the National Health Council and approved under number 67742 by the Ethics Research Committee.

Sample selection

The study included 35 white male subjects aged 18- 30 years, who do not exercise more than 2 times a week.

Exclusion criteria for this study were the following: individuals with biceps skinfold values above half the percentile of the triceps skinfold in the dominant limb; body fat percentage above 25%; obese; lack of full range of the elbow movement in the dominant limb; history of any surgical procedure in the dominant limb; absence of thermal and pain sensitivity; skin hypersensitivity to cold or heat; mental or behavioral factors that interfere in data collection; motor commitment of elbow flexors; cardiovascular disorders; neoplasms; inflammatory conditions in the dominant upper limb; active infections; metal implants, stents or external fixators. However, two individuals who had body mass index above 27 kg/m2 and biceps skinfold thickness over half the percentile of the triceps skinfold were excluded. Three individuals did not attend the evaluations; therefore, the sample consisted of 30 volunteers.

Variables

This work was conducted at the Physiotherapy Clinic of the Campos Gerais Higher Education Center, in a period of two months. Body weight (kg) and height (m) of volunteers were assessed through a Wiso® digital scale model W903, and an inelastic tape attached to the wall with no baseboard, respectively. From these values, body mass index (BMI) was calculated as the ratio between current weight and the square of the height of volunteers.

Then, the biceps skinfold of the dominant upper limb was assessed, and the volunteer was asked to remain with this limb relaxed, and using an inelastic tape, was measured the length between the acromion process of the scapula and the olecranon was measured and the midpoint was marked, and 2 cm above this point, the skin was pinched with Cescorf® plicometer.

After the collection of personal data, the volunteers were submitted to evaluation of the peak strength (PS) only of the right upper limb with the aid of a device (Figure 1) specifically developed for this research.

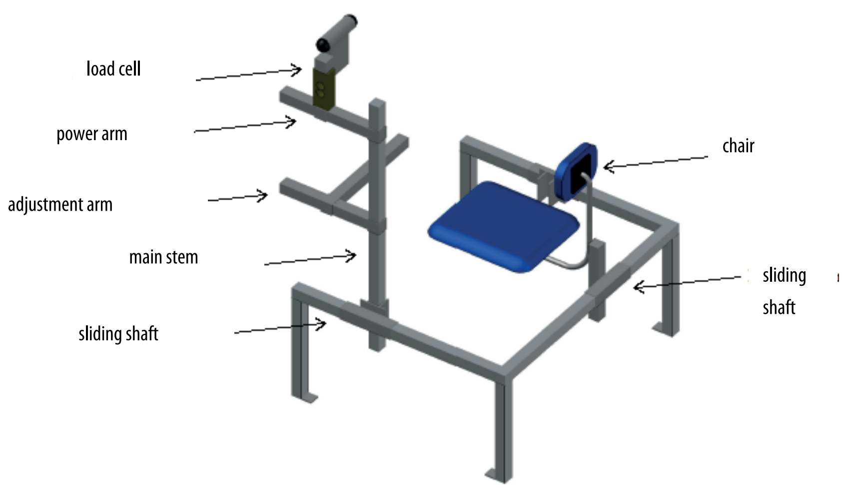

Figure 1. Components of the instrument designed to measure power and muscular torque

This equipment used a properly calibrated load cell to measure PS, and this value was given in Newtons (Figure 1). The load cell had 2.000 N of full scale.

This apparatus measured quantitatively PS exerted by the elbow flexor muscles. For this measurement, the volunteer was positioned in the device comfortable and fixed in shoulder flexion at 45°, this angle was measured by a Carci® mechanical goniometer. This position did not inhibit the action of the long portion of the biceps [12].

As verbal encouragement, participants were asked to perform a maximal voluntary isometric contraction (MVIC) for 6 seconds [13]. The PS value captured was shown on the device display and then recorded in the evaluation form. For the evaluation, three MVIC attempts were held, with two-minute interval between each attempt, considering the highest PS.

The study was conducted in two days with an interval of 48 hours between them and evaluations were performed at the same time. In order to minimize possible late effects of thermo-therapeutic resources, the sample was divided into two groups, half performed cryotherapy application and half performed MD application on the first day, on the next day, applications on the same volunteers were reversed (Figure 2).

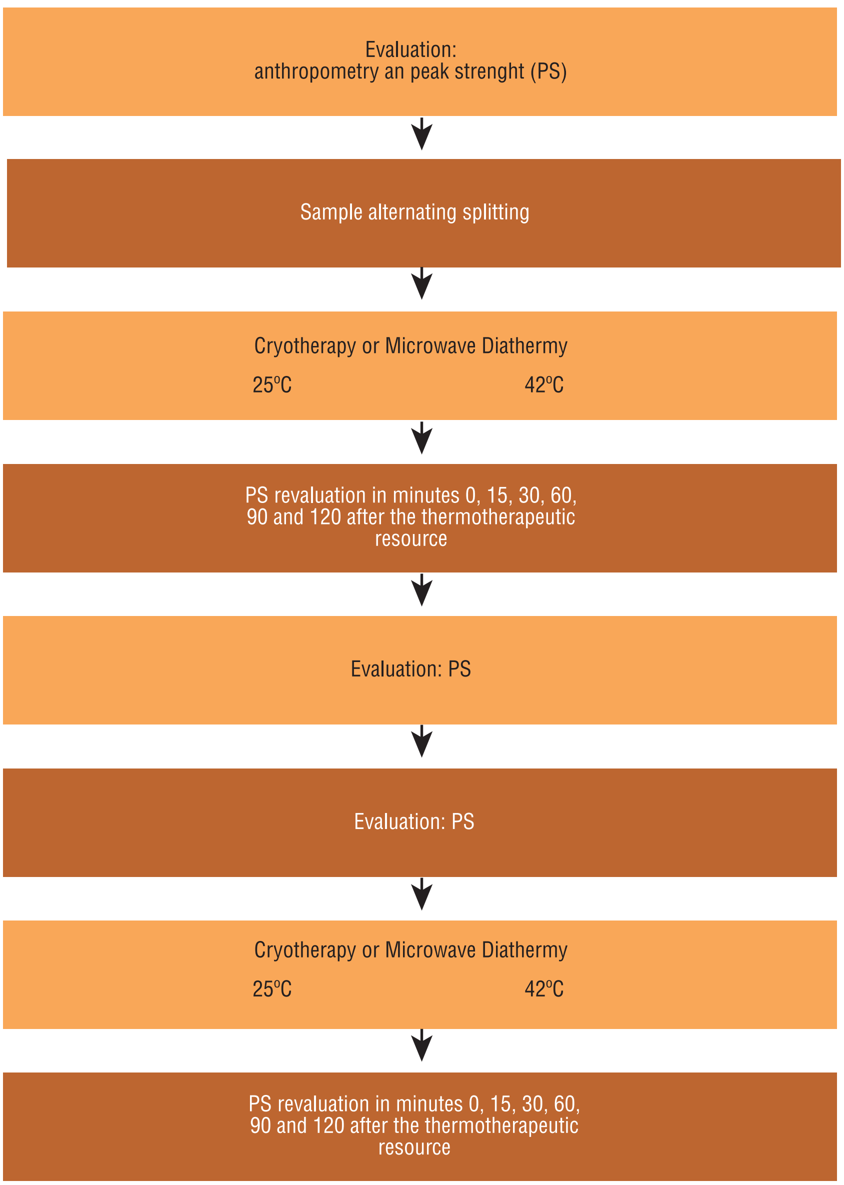

Figure 2. Flowchart of the study design

For application of cryotherapy, a plastic bag of approximately 500 g with crushed ice wrapped in a damp towel was used. The volunteer was positioned in sitting position with arm supported, and then the ice pack was placed on the biceps muscle.

An infrared thermometer brand Incoterm® scam Temp - 600.2-ST (with measurement range from 0 ° C to 50 ° C and accuracy of ± 2 ° C) was used to determine tissue temperature until the temperature measured by the thermometer in the biceps area reached 25°C.

For the MD application, Microtherm equipment label KLD® and a sandbag of approximately 500 g were used, which was placed between the volunteer's limb and the microwave oven irradiator. This technique generates a concentrated heating in the area involved [14]. The volunteer was positioned in supine position. Metal objects that could act as antennas when under the influence of the microwave radiation were removed, according to manufacturer's manual guidelines. The equipment that operates at a frequency of 2.45 GHz was adjusted in continuous mode with intensity according to the volunteer's tolerance and the application time was determined by the temperature measured with the aid of infrared thermometer up to reaching 42°C .

After applying the thermo-therapeutic resources, PS was reevaluated using the same steps of the first evaluation. This reevaluation was repeated immediately after, 15 min, 30 min, 60 min, 90 min and 120 min after application of the thermo-therapeutic resources.

Statistical analysis

Descriptive analysis was performed (mean, standard deviation and frequency distribution) to characterize the variables. As for the inferential statistics, the parametric Student t test for paired data was used, using 95% confidence intervals, p-value <0.05 as statistically significant.

RESULTS

The average age of volunteers was 22.40 (± 3.42) years. The mean BMI was 24.20 (± 2.26) kg / m^2 and biceps skinfold thickness was 4.53 (± 0.76) mm.

Figure 3 illustrates the PS in all evaluations.

Both thermo-therapeutic resources interfere with the muscle strength production capacity of elbow flexors.

There was a significant increase in PS 15 minutes after cryotherapy application, and from that time, there was a decrease of the maximum isometric strength; however, statistically significant difference compared to pre-application resource evaluation was present up to 90 minutes after as can be seen in Table 1. In addition, two hours after tissue cooling, PS had not returned to baseline (Figure 3).

PS significantly reduced up to 15 min after MD application. From this moment, PS was returned close to baseline (Figure 3). In the last assessment, PS reduced again and significantly (Table 1).

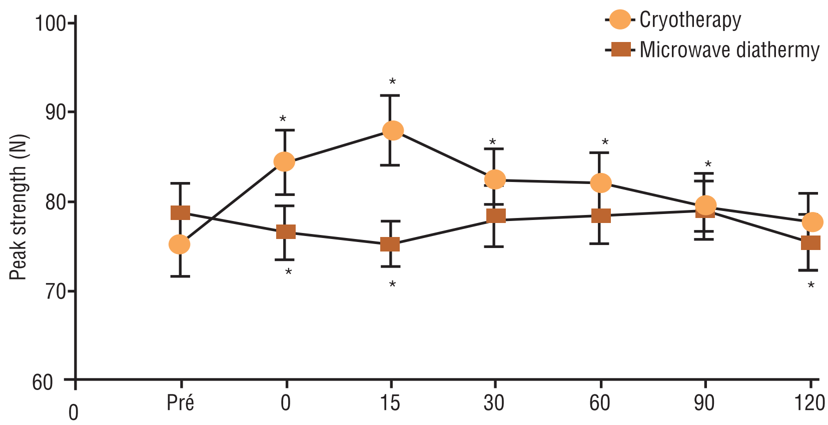

Figure 3. Mean muscle strength behavior
* Indicates statistically significant difference in relation to the pre-application of the thermal-resource. The average peak strength (PS) values of cryotherapy were: Pre-resource 75.13 (± 19.34), 0 min after 84.46 (± 19.89), 15 min after 88.03 (± 21.95), 30 min after 82.73 (± 17.04), 60 min after 88.22 (± 18.56), 90 min after 79.88 (± 17.40) and 120 min after 77.90 (± 17 23). The mean PS values of microwave diathermy were: Pre-resource 78.66 (± 18.68) after 0 min 76.63 (± 15.99) 15 min after 75.32 (± 14.98) 30 min later 78.40 (± 19.37) 60 min after 78.47 (± 18.08), 90 min after 79.01 (± 17.71) and 120 min after 75.41 (± 17 24).

Table 1. Comparison of the peak strength evaluation in each time after application of thermo-therapeutic resources with the pre-application of the resource and between thermo-therapeutic resources

Moment	Cryotherapy*	MD*	Cryotherapy X MD†
Pré			*0.000* ‡
0 minutes after	0.000	0.003	0.000 §
15 minutes after	0.000	0.001	0.000 §
30 minutes after	0.003	0.079	0.013 §
60 minutes after	0.007	0.068	0.022 §
90 minutes after	0.022	0.081	0.149 §
120 minutes after	0.065	0.015	0.067 §

MD - Microwave diathermy.
* Values obtained through the Student t test for paired data. † Values obtained through the Student t test for unpaired samples. ‡ P-value obtained using gross variables. § P-value obtained using the delta variation of every moment of every thermo-therapeutic resources. Significance value when $p \leq 0.05$.

DISCUSSION

The comparison of PS among thermo-therapeutic resources showed that cryotherapy caused a statistically significant increase up to one hour and 30 minutes after application. This increase in PS may have occurred due to the increased excitability of the motor fibers [8].

Although the study by Mortari et al. [2] did not show the temperature of muscles submitted to cooling, these authors showed a small increase in peak torque values in the flexion of lower limbs 15 minutes after cooling. Becher et al.[14] also showed that 30 minutes after cooling at ambient temperature to 19°C, higher PS of knee flexors was observed immediately after cold application; however, there was a decline in PS 60 minutes after cold application, but not below baseline.

In contrast to this study and others mentioned above, Halder et al.[15] investigated the effect of cooling in MVIC of anterior tibialis and gastrocnemius muscles using a dynamometer and found a significant reduction in anterior tibial strength. It is noteworthy that in this study, sample had legs submerged for 20 minutes in water at 10°C in a climate chamber also at 10°C.

In the last evaluation of this study (two hours after resource application), the maximum isometric strength continued to decline and showed no significant difference in relation to the pre-application. It is believed that this has occurred due to the increased tissue temperature.

In contrast to the findings of the present study, Tremblay et al [16] showed that tissue cooling does not change the perception of the imposed load, which indicates that the usual cryotherapy methods do not affect motor performance.

The same results were obtained by Rubley et al. [17], who studied the effect of immersion of flexor muscles of fingers in ice at 10°C for 15 minutes and reported that strength production is not affected by cooling, which was measured by strain gauges mounted on an apparatus built to measure the strength of fingers.

According to Cameron [7], depending on the duration time of application, cryotherapy may be associated with both increase and decrease of muscle strength, applications for shorter periods stimulate the nervous system, while long cooling affects the muscular metabolism, leading to decreased strength. This justifies the increased PS found in this study, since the time of application of cryotherapy to achieve 25 ° C was low, about two minutes, and the decline of strength in the above articles, since they reported longer times of resource application.

Regarding MD, muscle strength production capacity decreased after application (Figure 3). With increased temperature, muscle strength may decline initially, which may be due to changes in shutter speeds of motor fibers, which decreases the firing rate of alpha motor neurons, resulting in relaxation [8].

An increase in the PS value above the initial one hour and 30 minutes after application was observed, decreasing again below baseline two hours after application (Figure 3). Although deep heat increases metabolism, as well as nutritional support, it does not help the performance of isometric muscle strength of elbow flexor muscles [18]. Similar results were reported by Pereira et al [18], which, when evaluating the muscular strength of the elbow flexor using a load cell, showed that MD applied for 16 minutes leads to a significant reduction in muscle strength. Saga et al.[19] investigated the effect of heat at 41°C through MD for 20 minutes on PS through a computerized dynamometer and showed lower muscle strength, which proves that muscle temperature is an important factor of influence in isometric muscle strength. This can be explained based on the information that the increase in temperature can increase both the conduction velocity (lower temperatures) and block nerve conduction (higher temperatures) [20].

Dissimilarly to the above studies, a survey of 54 patients with osteoarthritis showed that the use of MD for 20 minutes three times a week increased muscle strength; however, this variable was measured through the British Medical Research Council scale and not by an objective measurement equipment [21].

Thus, considering only muscle PS, if the goal is to increase this variable, it is suggested cooling muscle to 25 ° C. However, if the goal is to decrease PS, it is suggested heating muscle to 42ºC.

It is worth mentioning that after reaching the recommended temperatures of 25 ° C and 42 ° C, cryotherapy and MD were not kept, and the maintenance of the thermo-therapeutic resources can be a changing factor in the behavior of the muscle strength.

Further studies are needed to prove the action of cryotherapy and MD on muscle strength production capacity and to analyze the application time associated with environmental temperature and muscle tissue to observe the change in PS.

CONCLUSION

Cryotherapy and MD interfere differently in the isometric muscle strength capacity of elbow flexors of healthy young men not physically active, and while cooling generates increment, heating causes decline.

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