ORIGINAL ARTICLE

Neuromuscular function of braquial biceps in isometric contraction after termotherapy

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ABSTRACT

The change in temperature of a biological tissue can promote physiological effects that lead to circulatory and nerve changes, such as vasodilation and increased flexibility. **Objective:** The objective of this study was to evaluate, through a noninvasive neuromuscular assessment, how thermotherapy influences the muscular strength and the myoelectric signals of the biceps brachial in isometric contraction. **Methods:** Seventeen volunteers were instructed to perform isometric contraction of the brachial biceps muscle concomitantly with surface electromyography. Electromyographic and force evaluation were performed before and after the intervention with thermotherapeutic resources that consisted of ice therapy for 15 minutes and continuous ultrasound (1MHz, 0.8W/cm^2) for 7 minutes. **Results:** Women have less strength and fewer motor units. However, the frequency of electric inputs of the effector pathways is higher, which indicates a greater propensity to fatigue. After the application of heat, no differences were observed in the neuromuscular response of the contracting brachial biceps. The cryotherapy, however, promoted a significant reduction in the strength and number of motor units activated during the contraction. **Conclusion:** The cooling of muscle tissue promotes a decrease of muscle fibers activities, since there is a reduction in the velocity of nerve impulse conduction and the reflex of the myotatic arch. In addition, cryotherapy also decreases the sensitivity of the Golgi tendon organs, increases blood viscosity, and causes vasoconstriction. All these factors are combined to culminate in the decrease of neuromuscular activation and, consequently, in the reduction of muscle strength.

Keywords: Electromyography, Ultrasonic Therapy, Cryotherapy, Muscle Strength

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INTRODUCTION

In Physical Therapy clinical practice, there are several electrotherapeutic and thermotherapeutic resources used in the rehabilitation of musculoskeletal system disorders. Thermotherapy is a modality that can interfere directly on these neural structures, specifically on the speed of nerve conduction. Here, the widespread use of heat and cold as therapeutic resources is associated with the broad spectrum of signs, symptoms and therapeutic modalities, which combined with the easy access and low cost, can enhance both the immediate and medium or long-term treatment.[1,2]

Heat or cold therapy have implications in the treatment of joint and skeletal muscle injuries and are systematically employed to relieve skeletal muscle pain. Felice & Santana define the application of heat as a therapeutic procedure that can be used by convection, conduction or radiation, whose effects cause increased tissue metabolic activity, vasodilation, decreased joint stiffness, and other effects. Therapeutic ultrasound, at a frequency between 1 and 3 MHz, is among the most widely used heat treatment methods.[3] When ultrasound is used, its beam propagates up to four layers of tissue: skin, hypodermis (fat), muscle and bone.[4] For deep tissue purposes, continuous ultrasound is used, whereas for the superficial tissues, the pulsed ultrasound suggested.[3] Cryotherapy, in its turn, consists in the use of ice in a therapeutic character for reducing metabolic activity, blood flow, edema, and for promoting pain relief.[4-8]

Surface electromyography (EMG) has been widely used in clinical applications and research in several areas of interest, including physiotherapy. It is used as an important method of noninvasive neuromuscular assessment in different scientific areas such as sports sciences, neurophysiology and rehabilitation.[9] Anatomical and physiological properties of muscle tissue, as well as the application of therapeutic approaches, can interfere in the control of peripheral nervous system and consequently in electromyographic signal.[10]

OBJECTIVE

Considering that muscle strength is an important parameter to diagnose etiology of diseases and to define and monitor rehabilitation strategies, this study sought to evaluate how heat and cryotherapy can interfere in the muscular strength of the biceps brachii, considering clinical parameters and surface electromyographic activity.

METHODS

This study was conducted with seventeen young volunteers, nine men and eight women. All volunteers reported they had good health, they did not exercise regular physical activity, nor did they use any pharmacological substance that would enhance muscular activity. Still as an inclusion criterion, no volunteer reported having a history of musculoskeletal injury and / or upper limb surgery.

Before performing the procedures, all subjects were instructed to remain seated at rest for about ten minutes in order to stabilize heart rate (HR) and blood pressure (BP). After this time, the volunteers were evaluated for physical parameters: height (stadiometer - Welmy, São Paulo, Brazil), total body mass (TBM) with a calibrated analytical scale, perimetry of upper limbs (midpoint between acromion and olecranon), in the relaxed and contracted condition, and skin folds of the biceps and triceps (adipometer - Sanny). They were also evaluated with a body control scale (bioimpedance) (Omron Healthcare, São Paulo, Brazil).

Thermotherapy

In this study, each volunteer was considered as their own control and they were all submitted to the use of cryotherapy and continuous ultrasound, with interval of 7-10 days between each test. All clinical evaluations described above were performed before each therapy. Regarding the point of the flexor musculature of the evaluated elbow, we defined the venter area of the brachial biceps muscle in a midline between the acromion and the ulnar fossa of the dominant limb. This positioning followed the recommendation of the SENIAM project (Biomedical Health and Research Program of the European Union for studies in Surface electronmyography for the non-invasive assessment of muscles).

To evaluate the effect of cold (cryotherapy), the volunteers were submitted to the application of crushed ice (1000 g), wrapped in a thin pancake cloth (60x60 cm), fixed to the limb by a non-elastic cotton bandage of twenty centimeters wide. The cryotherapy was maintained for 15 minutes, and the volunteer sit at rest with the arm extended, parallel to the trunk. To evaluate the effect of heat, the volunteers were submitted to continuous ultrasound (Sonopulse III, Ibramed, Brazil), adjusted at 1 MHz frequency (dose 0.8 W / cm^2) for 7 minutes in circular movements, and the volunteer was requested to sit with his arm along the chair.

After the application of ice or ultrasound, the perimetry of both upper limbs in the relaxed and contracted condition and the skin folds were again measured, both on the dominant and the contralateral sides.

Strength test

In order to evaluate the strength of the biceps brachii muscle, the volunteer sat in the upright position next to an inelastic apparatus attached to a dynamometer to keep the elbow at 90 ° (with or without height adjustments). The volunteer was instructed not to support the shoulder movement during flexion. After verbal command of the evaluator, the individual initiated isometric flexion of elbow with supination. The contraction was terminated under the order of the evaluator, in a maximum time of ten seconds, or in case of muscle pain / fatigue. The evaluator maintained verbal encouragement throughout the execution of the movement. At the end, the value of the force used in the dynamometer was evaluated (in kgf).

Electromyographic (EMG) evaluation

The electromyographic evaluation was performed with an EMG 830 C surface electromyograph (EMG System, São Paulo, Brazil), before and after thermotherapy, during the strength test. Adherent electrodes with 3.6cm diameter (3M) and conductive Ag/AgC gel, were used. A distance of 1 cm was observed between electrodes. The region was properly prepared by cleaning the area with 70° alcohol solution and gauze, under friction, in repetitive motions until local hyperemia. The electrodes were positioned on the brachial biceps muscle and the reference electrode was positioned in the C7 spinous process (according to SENIAM instructions). A period of 10 seconds was assessed in each evaluation. The results were collected according to mean root mean square (RMS) given by the apparatus for a predetermined period of 10 seconds. Fatigue analysis was performed by determining the median, also given by the device.

Statistical analysis

For data evaluation, a descriptive analysis (mean and standard deviation) was conducted. The t-test was performed to compare the means of the individual's physiological values, after cryotherapy and after ultrasound of all the parameters evaluated. In addition, Pearson correlation test was conducted for inferential analysis, which measures the intensity of the linear correlation between the means for two parameters (variables), in which a positive correlation is considered when both variables increase after the intervention and negative correlation is considered when one variable increases whereas the other decreases. Values above 0.7 indicate a strong correlation, between 0.3 and 0.7 there is moderate correlation, and, 0.3 or below shows poor or inexistent correlation. Evaluations on whether there was a correlation between the outcomes with sex (male / female) with analysis of variance (ANOVA), in which the degree of significance of the test indicates whether the means between the groups are equal. The statistical analysis was conducted with the softwares Graph Pad Prism and SPSS, whereas the untreated data was kept in Excel sheets.

This research was approved by an Ethics Review Board with registration 54831816.2.0000.5139. All volunteers signed the Informed Consent Form, according to the Brazilian National Health Council resolution 466/12.

RESULTS

Table 1 shows the clinical characteristics of the 17 volunteers of this study. There were 9 males and 8 females, with 22.53 ± 3.78 years of age. Regarding the anthropometric data, we observed that the male volunteers presented higher body mass index (BMI) (27.02) and the body adiposity index (BAI) (26.4%), both of which corresponded to overweight (26.4%).

To characterize other physical and metabolic parameters, a bioimpedance test was conducted (Table 2). In this test, the volunteers presented body age (37.24 ± 14.20) well above the "chronological" age (22.53 + 3.78). Table 3 shows the correlation of these parameters with sex, in which the highest percentage of visceral fat and skeletal muscle are strongly correlated to male sex (p=0.006, and p=0.000, respectively), unlike body fat, which is higher among females (p=0.001).

In table 3 it is possible to see that the men presented greater perimetry of the limbs, when compared to the women (p <0.05). However, for both sexes, no differences were observed in the measurement of the dominant and contralateral limbs. The women presented a greater measure of skinfolds in both limbs (Table 3).

In the dominant limb, men have significantly greater strength than women (p<0.01) (Table 3).

Table1. Clinical characteristics of the volunteers

Volunteer	Sex	Dominant Limb	Age	HF (bpm)	Weight (kg)	Hight (m)	Hip circumference (cm)	BAI (%)	BMI
1	M	R	24	74.0	66.8	1.70	94.50	24.63	23.11
2	M	R	20	76.0	94.8	1.83	106.50	25.02	28.29
3	M	R	30	78.0	74.5	1.74	98.25	24.99	24.75
4	M	R	21	75.0	71.0	1.76	99.25	24.51	22.92
5	M	R	18	77.0	112.0	1.79	117.50	31.06	34.94
6	M	L	27	69.0	83.5	1.68	106.25	30.79	29.58
7	M	L	20	80.0	99.2	1.76	109	28.68	32.02
8	M	R	24	76.5	73.8	1.75	99.5	24.98	24.08
9	M	R	23	77.5	67.8	1.70	91.25	23.17	23.44
Mean			23,00	75,89	82.58	1.75	102.44	26.43	27.02
10	F	R	20	71.5	74.8	1.56	104.75	35.76	30.72
11	F	R	31	82.0	46.8	1.57	85.00	25.21	18.97
12	F	R	22	77.5	54.7	1.53	96.00	32.98	23.50
13	F	R	20	74.5	52.0	1.60	87.00	24.99	20.31
14	F	R	22	74.0	62.8	1.69	100.00	27.52	21.97
15	F	R	18	84.5	74.0	1.60	102.5	32.65	28.91
16	F	R	23	84.5	68.2	1.66	105.25	31.21	24.73
17	F	R	20	84.0	61.0	1.58	101	33.10	24.59
Mean			22,00	79,06	61.76	1.60	97.69	30.43	24.21
Mean (overall)			22.53	77.38	72.78	1.68	100.21	28.31	25.70
SD (overall)			3.78	4.46	16.96	0.09	8.09	3.95	4.34

M, male; F, female; R, right upper limb; L, left upper limb; HF, heart frequency (beats per minute); BAI, body adiposity index; BMI, body mass index; SD, standard deviation

Table 2. Bioimpedance results of the volunteers

Volunteer	Sex	Weight	BMI	Visceral fat (%)	Body fat (%)	Basal metabolism	Skeletal muscle (%)	Body age
1	M	66.50	22.90	5.50	19.90	1606.00	40.30	24.5
3	M	94.70	28.25	9.50	27.40	1982.50	35.80	55
4	M	74.40	24.70	7.00	23.25	1693.00	37.65	37.5
5	M	71.10	22.95	5.00	19.60	1646.00	41.20	27.5
6	M	111.95	34.90	13.50	29.60	2219.50	34.60	68.5
11	M	82.40	29.15	11.50	29.10	1821.50	35.35	46
14	M	96.70	31.20	12.00	28.60	2023.00	35.55	56.5
16	M	73.30	23.50	6.00	23.35	1679.00	37.65	34.5
17	M	67.80	23.45	5.00	13.35	1651.00	44.90	23
	Mean	82,09	26.78	8.33	23.79	1813.50	38.11	41.4
7	F	73.95	33.50	6.00	46.75	1386.50	22.90	48.5
8	F	47.60	19.30	3.00	23.10	1153.50	31.60	21.5
9	F	55.30	23.75	5.00	38.75	1205.50	23.70	34.5
10	F	51.45	20.10	3.00	31.25	1227.50	24.80	18
2	F	62.75	21.85	3.00	31.40	1358.00	28.85	22.0
12	F	73.30	28.65	5.00	42.05	1410.00	25.50	42.5
13	F	71.90	26.10	5.00	42.00	1422.00	24.10	38
15	F	61.20	24.70	4.50	39.50	1277.50	24.60	35
Mean		62,18	24.74	4.31	36.85	1305.06	25.76	32.5
Mean (overall)		72.72	25.82	6.44	29.94	1574.24	32.30	37.2
SD (overall)		16.55	4.48	3.23	9.27	309.85	7.07	14.2

M, male; F, female; BMI, body mass index; SD, standard deviation

Table 3. ANOVA tests of correlation between males and females and clinical and physical parameters, as well as strength measured by electromyographic parameters of the dominant limb.

	Male mean	Female mean	F	p-value
Body age	41.44	32.50	1.761	.204
Visceral fat	8.33	4.31	10.431	.006*
Body fat	23.79	36.85	16.592	.001*
Skeletal muscle percentage	38.11	25.76	63.024	.000*
BAI	26.43	30.43	5.587	.032*
BMI	27.01	24.21	1.863	.192
Weight	82.60	61.79	9.943	.007*
Age	23.00	22.00	0.284	.602
Relaxed dominant perimeter (mm)	32.89	27.86	7.336	.017*
Contracted dominant perimeter (mm)	34.44	28.57	12.039	.004*
Dominant triceps skin fold (mm)	16.04	20.70	5.568	.032*
Dominant biceps skin fold (mm)	7.78	11.03	3.436	.084
Strength (kgf)	3.06	1.55	32.674	.000
RMS	1014.76	553.48	6.109	.026
Median	76.15	113.66	5.431	.034

Data on body age, visceral and body fat, and skeletal muscle was given by bioimpedance; RMS, root mean square; F, statistical variance between groups; * p<0.05; n=17 (9 males and 8 females).

In electromyography analysis, according to the root mean square value (RMS), this result is justified by the fact that men activate about 80% more motor units than women (p=0.026). Table 3 also shows that, despite activating fewer motor units, the signal (frequency of firing) is significantly higher in women (p=0.034).

The table 4 shows that brachial biceps muscle strength, evaluated by surface electromyography, is significantly influenced by the following parameters: visceral fat (p=0.015), body fat (p=0.018), skeletal muscle (p=0.005), BAI (p=0.053), weight (p=0.003), triceps skin fold (p=0.026) and biceps brachii (p=0.055). The percentage of body fat and skeletal muscle measured with bioimpedance also interfere with RMS and median values, as well as strength (p <0.05) (Table 4).

After the thermotherapeutic application (ice or ultrasound), no differences were observed in the perimetry of the dominant and contralateral limbs, as well as in the skin folds (data not shown). The strength, RMS and median data collected after thermotherapy are shown in table 5. With these data, it is possible to observe that the application of the continuous ultrasound at 1 MHz, 0.8 w / cm^2, for 7 min, did not interfere in any of the evaluated parameters. However, the application of ice on the brachial biceps muscle reduces muscle strength (p<0.01) and the number of motor units activated, as observed in the RMS value (p=0.05). Regarding RMS, it is important to emphasize that, in males, ice reduces motor activation by 41%, while in females, this reduction is only 5%. Nonetheleess, ice application does not alter the conduction velocity of the potential of action in the brachial biceps muscle cells, as observed by median (Table 5).

DISCUSSION

In this study, we evaluated whether widely used thermotherapeutic resources, ice and ultrasound, interfere with the strength of the elbow flexor muscles and, through correlation tests, which factors may interfere with the neuromuscular activity, measured by surface EMG. EMG is a noninvasive evaluation technique applied in physical therapy assessments that evaluates the electrical activity of motor units and skeletal muscle fibers.[9,10]

The volunteers showed a strong correlation between the higher percentage of visceral fat and skeletal muscle in men, who, by the parameters of BMI and BAI, were classified clinically as overweight individuals. Regarding body fat, it was observed that this parameter is strongly correlated to females and this measured by the greater occurrences of skinfolds. When we compare the electromyographic activity between men and women we observed that, in isometric contraction, women have less strength in the biceps brachii. This fact can be explained by the activation of a smaller number of motor units (MU), however, the values obtained by the median show that the frequency of firing in each muscle fiber was higher, making them more prone to fatigue.[11]

These results and differences between the genders can be explained by the body constitution of the male, who, in relation to the women, have a greater perimeter of the dominant limb, 68% more skeletal muscle and 55% less body fat (cystometry, bioimpedance and skinfolds). The results obtained in our correlation tests (Table 5) agree with the literature, which shows that the electromyographic reading is determined not only by the number of muscle fibers and MU, but also by the thickness of the adipose tissue layer, which impairs the uptake of electrical signals.[12-14]

Continuous ultrasound is a therapy to promote tissue warmth and, consequently, vasodilation, increased enzymatic activity, increased collagen extensibility and nerve conduction velocity, improving the contractile activity of the skeletal muscle.[15-19] Much is said about the parameters related to the application dose. The literature has many articles that discuss different protocols, making it difficult to relate treatment parameters to clinical outcomes.[20-23] However, it is known that 2°C increase corresponds to a 20% increase in contraction speed of muscle tissue.[17] We emphasize that the higher the frequency, the greater the absorption of the ultrasound waves[24-27] and that, for the therapeutic ultrasound to produce the desired thermal effect, it is necessary to heat the tissue up to 40 to 45°C for at least 5 minutes.[6,28-30,31] In this context, Gallo et al.[32] described the increase of 2.8° + 0.8°C in the gastrocnemius muscle (3 MHz, 1.0 W / cm^2, for 10 minutes), was not enough cause thermal effect. In this study we did not observe any changes in the parameters of strength. Although they used pulsed ultrasound, Wilkin et al.[33] did not observe benefits in the application of ultrasound in the injured gastrocnemius muscle of rats as well.

Continuous ultrasound heat generation and its application as a thermotherapeutic resource has been questioned, since it can suffer the interference of many factors, including the amount of protein and fat of the treated tissue [6,20,21,31] and there is no technique that limits ultrasound absorption to a single specific type of tissue.[34] Several authors argue that collagen-rich tissues (fascia, tendons, ligaments) are the ones that better absorb the ultrasound radiation.[31,35-39] Other therapies, such as short-wave therapy, are more effective in producing a thermal effect compared to ultrasound.[40] However, to optimize results, another study showed that ultrasound and laser, despite being two different energies, were complementary in promoting greater tissue heating.[34]

Table 4. Pearson correlation test for clinical parameters of strength and electromyography of dominant limb

	Body age	Visceral fat	Body fat	Skeletal muscle (%)	BAI	BMI	Weight	Age	Relaxed perimeter	Contracted perimeter	Triceps skin fold	Biceps skin fold	Strength	RMS	Median	Mediana
Body age	Cor. Pearson	1	.875**	.318	-.036	.481	.949**	.894**	-.385	.445	-.063	.379	.379	.428	-.019	-.183
	Sig. (bilateral)	#	**.000**	.214	.892	**.051**	**.000**	**.000**	.127	.073	.810	.134	.133	.087	.944	.482
Visceral fat	Cor. Pearson	.875**	1	-.071	.317	.171	.858**	.923**	-.171	.327	-.253	.107	.189	.580*	.115	-.338
	Sig. (bilateral)	**.000**	#	.787	.216	.511	**.000**	**.000**	.511	.200	.328	.684	.467	**.015**	.661	.184
Body fat	Cor. Pearson	.318	-.071	1	-.923**	.897**	.316	-.045	-.431	.456	.264	.869**	.806**	-.567*	-.492*	.486*
	Sig. (bilateral)	.214	.787	#	**.000**	**.000**	.217	.864	.084	.066	.306	**.000**	**.000**	**.018**	**.045**	**.048**
Skeletal muscle (%)	Cor. Pearson	-.036	.317	-.923**	1	-.739**	-.001	.333	.299	-.308	-.258	-.756**	-.685**	.747**	.580*	-.565*
	Sig. (bilateral)	.892	.216	**.000**	#	**.001**	.996	.192	.244	.230	.317	**.000**	**.002**	**.001**	**.015**	**.018**
BAI	Cor. Pearson	.481	.171	.897**	-.739**	1	.524*	.131	-.397	.326	.165	.853**	.841**	-.477	-.446	.381
	Sig. (bilateral)	**.051**	.511	**.000**	**.001**	#	**.031**	.616	.114	.201	.527	**.000**	**.000**	**.053**	.073	.132
BMI	Cor. Pearson	.949**	.858**	.316	-.001	.524*	1	.894**	-.467	.470	-.104	.417	.443	.362	.006	-.129
	Sig. (bilateral)	**.000**	**.000**	.217	.996	.031	#	**.000**	**.059**	**.057**	.691	.096	.075	.153	.980	.622
Weight	Cor. Pearson	.894**	.923**	-.045	.333	.131	.894**	1	-.373	.344	-.212	.092	.093	.681**	.230	-.343
	Sig. (bilateral)	**.000**	**.000**	.864	.192	.616	**.000**	#	.141	.177	.415	.725	.723	**.003**	.374	.177
Age	Cor. Pearson	-.385	-.171	-.431	.299	-.397	-.467	-.373	1	-.314	.262	-.322	-.243	-.090	.042	-.325
	Sig. (bilateral)	.127	.511	.084	.244	.114	**.059**	.141	#	.220	.309	.208	.347	.732	.874	.204
Relaxed perimeter	Cor. Pearson	.445	.327	.456	-.308	.326	.470	.344	-.314	1	.131	.323	.456	.149	-.189	.094
	Sig. (bilateral)	.073	.200	.066	.230	.201	**.057**	.177	.220	#	.615	.206	.066	.568	.468	.719
Contracted perimeter	Cor. Pearson	-.063	-.253	.264	-.258	.165	-.104	-.212	.262	.131	1	.132	.195	-.182	.110	-.031
	Sig. (bilateral)	.810	.328	.306	.317	.527	.691	.415	.309	.615	#	.614	.454	.485	.674	.906
Triceps skin fold	Cor. Pearson	.379	.107	.869**	-.756**	.853**	.417	.092	-.322	.323	.132	1	.904**	-.538*	-.490*	.298
	Sig. (bilateral)	.134	.684	**.000**	**.000**	**.000**	.096	.725	.208	.206	.614	#	**.000**	**.026**	.046	.245
Biceps skin fold	Cor. Pearson	.379	.189	.806**	-.685**	.841**	.443	.093	-.243	.456	.195	.904**	1	-.474	-.353	.304
	Sig. (bilateral)	.133	.467	**.000**	**.002**	**.000**	.075	.723	.347	.066	.454	**.000**	#	**.055**	.164	.235
Strength	Cor. Pearson	.428	.580*	-.567*	.747**	-.477	.362	.681**	-.090	.149	-.182	-.538*	-.474	1	.527*	-.521*
	Sig. (bilateral)	.087	**.015**	**.018**	**.001**	**.053**	.153	**.003**	.732	.568	.485	**.026**	**.055**	#	**.030**	**.032**
RMS	Cor. Pearson	-.019	.115	-.492*	.580*	-.446	.006	.230	.042	-.189	.110	-.490*	-.353	.527*	1	-.417
	Sig. (bilateral)	.944	.661	**.045**	**.015**	.073	.980	.374	.874	.468	.674	**.046**	.164	**.030**	#	.096
Median	Cor. Pearson	-.183	-.338	.486*	-.565*	.381	-.129	-.343	-.325	.094	-.031	.298	.304	-.521*	-.417	1
	Sig. (bilateral)	.482	.184	**.048**	**.018**	.132	.622	.177	.204	.719	.906	.245	.235	**.032**	.096	#

Data on body age, visceral and body fat, and skeletal muscle was given by bioimpedance; * p<0.05; ** p<0.01; n=17; BAI, body adiposity index; BMI, body mass index.

Cryotherapy is a technique that is being widely used, especially in sports, since cooling of muscle tissue promotes a decrease in the action of fibers and consequent muscle relaxation, increasing the patient's pain threshold. This can be explained by the speed reduction of nerve impulse conduction and the reduction of the reflex of the myotatic arch.[7,8,20,28-33]

Seward & Rutkove report that the decrease in temperature reduces the rate of opening and, more importantly, closing of the sodium channels.[41] Maintenance of the opened channel for a longer time makes depolarization and repolarization slower, reducing the rate of nerve conduction and, consequently, produces a longer duration response.[41] In our study, when the same volunteers were submitted to the cryotherapy protocol, we observed that the tissue cooling was able to significantly reduce the strength of the ischemic contraction of the brachial biceps muscle. This reduction in strength was accompanied by a decrease in MU activation. These results agree with several publications, in the most diverse muscle groups, times of application and forms of tissue cooling, which also emphasize the reduction of muscle strength.[7,20,26,41-45]

Several authors point out that the strength of a given muscle group is closely related to the sensitivity of golgi tendinous organ (GTO, related to the intensity of contraction) and muscle spindles (regulating fiber length variation).[7,8,20,41,46-51] In addition to the effect on the sensory receptors (OTG and muscle spindle), the effect described herein may have other explanations that may be unique or may add to the final effect. We emphasize that cooling increases the viscosity of blood

Table 5. Strength results (kgf), RMS and median after thermotherapy (ice or ultrasound)

Sex	Strength (kgf)			RMS			Median		
	Physiologic	Ice	Ultrasound	Physiologic	Ice	Ultrasound	Physiologic	Ice	Ultrasou-nd
M	2.40	2.20	2.30	763.88	646.44	706.74	72.74	41.25	67.62
M	4.60	3.40	3.20	895.19	550.20	834.54	89.60	60.05	91.55
M	2.25	2.30	2.10	1107.53	740.31	1222.92	68.84	119.87	119.87
M	3.10	2.80	3.10	857.82	350.85	767.45	81.66	119.87	106.93
M	3.05	3.50	3.00	1021.40	605.11	1142.29	53.34	119.87	47.85
M	2.50	2.50	2.50	577.10	700.93	493.56	92.53	120.11	70.80
M	3.15	3.00	3.40	602.37	470.02	963.65	76.66	46.87	80.81
M	3.15	2.10	3.50	1336.08	911.08	1013.60	87.40	119.87	100.09
M	3.30	3.50	2.90	1971.52	424.38	1981.19	62.62	62.98	59.08
Mean	3.06	2.81	2.89	1014.76	599.92	1013.99	76.15	90.08	82.73
F	1.65	1.60	1.60	518.82	311.45	644.40	126.70	208.98	139.16
F	1.45	1.40	1.50	547.31	777.90	120.11	155.88	317.67	76.17
F	1.70	1.40	1.60	201.59	433.97	430.43	63.96	87.89	60.30
F	1.30	1.30	1.20	386.38	388.17	319.05	105.35	58.83	58.10
F	1.15	0.80	0.90	645.60	789.64	159.12	148.68	120.36	218.99
F	1.85	1.20	1.60	331.77	229.56	185.86	79.59	137.45	104.73
F	1.95	1.80	1.80	1268.18	838.76	453.05	50.53	110.11	58.59
F	1.35	1.10	1.80	528.24	437.34	615.23	178.59	125.00	156.00
Mean	1.55	1.33	1.50	553.48	525.85	365.91	113.66	145.79	109.01
Overall mean	2.35*	2.11*	2.24	797.69**	565.07**	709.01	93.80	116.30	95.10
SD	0.94	0.89	0.82	441.16	203.77	469.34	37.43	66.31	44.18

*RMS – root mean square; M, male; F, female; SD, standard deviation; * p<0,01; ** p<0.05*

circulating, as well as the sensitivity of calcium to the actin-myosin complex, interfering in the connections between the actin and myosin cross-bridges that form the muscle fibers.[7,20.26,51]

CONCLUSION

As observed in the medical clinic and physical therapy, when compared to men, women have less strength and a greater propensity to muscle fatigue in the biceps brachii. The application of heat through continuous ultrasound was not able to alter the neuromuscular response and strength. In contrast, cryotherapy is a feature that, when applied directly on the muscle (pancake), causes a decrease in the activation of motor plates of the biceps brachii, significantly reducing the strength of this muscle. In our work, it was possible to measure the temperature of the tissue and we suggest the physiotherapists to monitor patients who receive cryotherapy and ultrasound, once after the application of the ice, if the patient is submitted to maneuvers that require muscle strength, the chance of osteomioarticular injury due to effort / repetition increases.

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