

# Effect of cryotherapy on the electromyographic response of the tibialis anterior, peroneus longus and gastrocnemius lateralis muscles in athletes after ankle inversion movement

*Efeito da crioterapia na resposta eletromiográfica dos músculos tibial anterior, fibular longo e gastrocnêmio lateral de atletas após o movimento de inversão do tornozelo*

*Efecto de la crioterapia en la respuesta electromiográfica de los músculos tibial anterior, fibular largo y gastrocnêmio lateral de atletas después del movimiento de inversión del tobillo*

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**ABSTRACT** | Cryotherapy is often indicated in the treatment of ankle/foot injuries in athletes; however, there is some controversies regarding its action on motor control. The main objective was to evaluate the effects of cryotherapy on electromyographic response of the ankle muscles in athletes after inversion. The sample consisted of 20 volunteers: 10 university basketball athletes and 10 non-athletes. All athletes were submitted to ankle inversion for the analysis of the EMG signals of Lateral Gastrocnemius (LG), Tibialis Anterior (TA) and Fibular Longus (FL) muscles, before and immediately after ankle immersion in cold water at  $4\pm 2^{\circ}\text{C}$ , for 20 minutes. The peak Root Mean Square (RMS) values were analyzed between 0 to 0.2 seconds and between 0 to 1 second after a sudden inversion on a tilting platform. Data were normalized by the peak RMS measured before cold water immersion. The statistical analysis was performed using Shapiro Wilk, Wilcoxon and Mann-Whitney tests. The level of significance was set at 5%. The results showed that the RMS values were lower in TA muscle of athletes, and up to 0.2 seconds in LG and FL muscles of non-athletes; up to 1 second, there was lower LG, TA and FL muscle recruitment in non-athletes. The comparison between athletes and non-athletes showed, in RMS up to 1 second, lower GL muscle recruitment in athletes submitted to pre cold water immersion and TA muscle pre and after cooling. Cryotherapy decreased the electromyographic response of TA muscle in athletes and of LG, TA and FL muscles in non-athletes.

**Keywords** | Cryotherapy; Electromyography; Ankle; Athletes; Physical Therapy Specialty.

**RESUMO** | A crioterapia é utilizada para tratamento de traumas no tornozelo/pé em atletas; entretanto, sua ação sobre o controle motor apresenta controvérsias. Este estudo objetivou verificar o efeito da crioterapia na resposta eletromiográfica dos músculos do tornozelo de atletas após inversão. A amostra foi composta por 20 voluntários: 10 universitários atletas de basquetebol e 10 universitários não atletas. Todos foram submetidos à inversão do tornozelo em plataforma para a análise do sinal eletromiográfico dos músculos Gastrocnêmio Lateral (GL), Tibial Anterior (TA) e Fibular Longo (FL), pré e pós-crioterapia por imersão do tornozelo, a  $4\pm 2^{\circ}\text{C}$ , por 20 minutos. A análise estatística utilizou o teste de Shapiro Wilk, Wilcoxon e Mann-Whitney, com nível de significância em 5%. Considerou-se o pico de RMS, o RMS após 0,2 segundos e após 1,0 segundo da abertura da plataforma de inversão. Todos os dados foram normalizados pelo pico do RMS no momento pré-crioterapia. Evidenciou-se diminuição do pico do RMS e do RMS até 0,2 s para o TA nos atletas e nos músculos GL e FL dos não atletas. Após um segundo da abertura da plataforma houve menor recrutamento dos músculos GL, TA e FL para os não atletas. A comparação entre atletas e não atletas apontou, no RMS até 1 segundo, menor recrutamento para o GL dos atletas pré-crioterapia e TA pré e após o resfriamento. Conclui-se que a crioterapia diminuiu a resposta eletromiográfica do músculo TA de atletas e GL, TA e FL de não atletas.

**Descritores** | Crioterapia; Eletromiografia; Tornozelo; Atletas; Fisioterapia.

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**RESUMEN** | La crioterapia es utilizada para tratamiento de traumas en el tobillo/pie en atletas; entre tanto, su acción sobre el control motor presenta controversias. Este estudio intentó verificar el efecto de la crioterapia en la respuesta electromiográfica de los músculos del tobillo de atletas después de inversión. La muestra fue compuesta por 20 voluntarios: 10 universitarios atletas de básquetbol y 10 universitarios no atletas. Todos fueron sometidos a inversión del tobillo en plataforma para el análisis de la señal electromiográfica de los músculos Gastrocnemio Lateral (GL), Tibial Anterior (TA) y Fibular Largo (FL), pre y post-crioterapia por inmersión del tobillo, a  $4\pm 2^{\circ}\text{C}$ , durante 20 minutos. El análisis estadístico utilizó el test de Shapiro Wilk, Wilcoxon y Mann-Whitney, con nivel de significación de 5%. Se consideró el pico de RMS, el RMS después de 0,2 segundos y

después de 1,0 segundo de la apertura de la plataforma de inversión. Todos los datos fueron normalizados por el pico del RMS en el momento pre-crioterapia. Se evidenció disminución del pico del RMS y del RMS hasta 0,2 s para el TA en los atletas y en los músculos GL y FL de los no atletas. Después de un segundo de la apertura de la plataforma hubo menor reclutamiento de los músculos GL, TA y FL para los no atletas. La comparación entre atletas y no atletas señaló, en el RMS hasta 1 segundo, menor reclutamiento para el GL de los atletas pre-crioterapia y TA pre y después del enfriamiento. Se concluye que la crioterapia disminuyó la respuesta electromiográfica del músculo TA de atletas y GL, TA y FL de no atletas.

**Palabras clave** | Crioterapia; Eletromiografía; Tobillo; Atletas; Fisioterapia.

## INTRODUCTION

The ankle articulation represents 34.3% of all sports related injuries<sup>1</sup>, where the inverted sprain is also more common among physically active individuals<sup>2</sup>. Epidemiological studies estimate that the incidence of sprained ankles in general population is about 5 to 7 torsions every thousand people a year; worldwide, approximately one ankle sprain occurs within every 10.000 people per day<sup>3</sup>.

After an ankle injury, the cryotherapy is recommended as treatment to both elite and amateur athletes, for specific therapeutical purposes<sup>4</sup>. Its efficiency is asserted through diminishing of the pain, swelling, inflammation, blood flow, metabolic rate, intramuscular temperature, hypertonicity and nervous conduction speed<sup>5</sup>. Many are the applications in use, such as immersion in cold water, thermoelectric cooling, dry ice and ice packs, with an estimated application time between 15 and 30 minutes<sup>6</sup>.

It is known that the therapeutical usage of cold gradually reduces the transmission of impulses in sensory nerves, due to the reduction in conduction speed within nervous fibers<sup>7</sup>, which decreases proprioception and increases the risk of injuries, due to minor muscular strength, proprioceptive afferents or a combination of those<sup>8</sup>. Cryotherapy's negative effects in motor control are also pointed out for reducing muscular torque, for inappropriate peripheral feedback for proprioception and for the alteration of the biomechanical properties of articulations, leading to injuries during the practice of exercises<sup>9</sup>. Also, an overload in exercise execution posterior to the cooling of the muscles, can lead to a new muscular injury, once motor control is altered<sup>10</sup>.

In order to assess the effects of cryotherapy on muscle recruitment an surface electromyography may be used. Cordova *et al.*<sup>11</sup> and Berg *et al.*<sup>12</sup> have observed

that the cooling had not altered the latency or amplitude of the response of the Fibular Longus muscle to the movement of ankle inversion. On the other hand, Schmid, Moffat and Gutierrez<sup>13</sup> claim that, despite all controversies, some studies indicate cryotherapy to decrease muscular activity, associated with high rates of injuries when returning to sports practice/games. Considering the conflicting data regarding cryotherapy and the electromyographic response, and the fact that many athletes immediately return to their competition activities<sup>14</sup>, the hypothesis the present study explores is that the cooling of the foot and ankle decreases the electromyographic response in muscles related to the articulation, during the inversion movement. Thus, the aim was to point out the effects of cryoimmersion of the foot and ankle at the peak of electromyographic response of LG, TA and FL muscles, after passive ankle inversion movement of athletes.

## METHODOLOGY

The survey was carried out at the Laboratório de Análise do Movimento do Centro de Reabilitação do Hospital das Clínicas, Faculdade de Medicina de Ribeirão Preto da Universidade de São Paulo (FMRP-USP), in accordance to the Resolution 466/2012 of the Conselho Nacional de Saúde, this study was approved by the Comitê de Ética em Experimentação com Seres Humanos, Hospital das Clínicas-FMRP/USP (Plataforma Brazil – 2968/2010) and registered as clinical trial (*Clinical Trial*/NCT01870414).

For putting a convenience sample together, 20 subjects have been recruited, being those of male gender, college students, between 18 and 28 years of age, BMI

between 20 and 24 kg/m<sup>2</sup>, with no records of acute lower limb injuries as well as no pain complaints. Of those, 10 were college basketball athletes, in training routine of a minimum three-day-program a week, having no withdraw from sport activities in the last six months, who have formed the athletes group. The other 10 volunteers were healthy, active subjects, who have formed the non-athletes group.

During the recruiting process, subjects who had undergone surgical procedures or with either muscular or articular injuries in lower limbs, in the last six months, were excluded; also were excluded individuals diagnosed with debilitating metabolic, rheumatic and orthopedic pathologies; with cognitive or balance disorders; individuals complaining of muscle fatigue at the moment of the tests or even the ones who required the use of stabilizers in order to accomplish them; ones with skin lesions in lower limbs and hypersensitivity to cold temperatures. As it was a convenience sample, there were no losses.

Data collection was developed with EMG Myomonitor IV (Delsys®, Boston, MA, USA), 10<sup>9</sup> Ohms impedance, 16-bit resolution, input range ±1V, sampling frequency of 1000Hz, band pass 20–450 Hz, signal noise ratio ≤1.2 uV RMS, microcomputer interfaced, with a gain of 1,000 times. The simple differential surface sensor (Delsys®, Boston, MA, USA) had silver contact bars (10 x 1 mm), spaced at 10mm, gain amplified in 10 V/V ±1%, Rejection Index by Common Modulation of 92 dB and impedance >10<sup>15</sup>Ω//0.2 pF. For the acquisition, storage and analysis was used the *Data Acquisition Software* (Delsys®, Boston, MA, USA).

For the placement of the electrodes, the volunteer would stand up, while shaving, skin cleansing and coupling of the sensors on the LG, TA and FL muscles were conducted, as proposed by the *Surface EMG for Non-Invasive Assessment of Muscles* (SENIAN), fixed by double-sided adhesive tape and elastic band. Next, the subject was positioned on an inversion platform, standing upright, opened eyes and bare feet (Figure 1A), synchronized with the electromyograph and activated by the computer. The collection of the data consisted on six sudden and unexpected movements of ankle inversion to 30 degrees (Figure 1B), three to each side, randomly. The electromyograph data collection was performed by blinded assessor, who has not taken part in the analysis, tabulation nor data description.

After the initial electromyographic evaluation, the subjects were positioned sitting down, with lower limbs positioned at 90 degrees; then, the extremity of the dominant lower limb was submitted to immersion

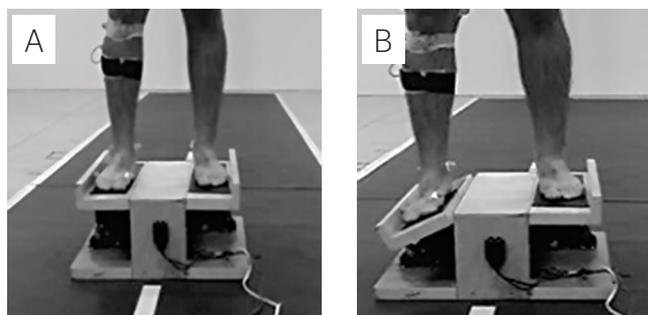


Figure 1. Initial moment (A) and final (B) of the opening of the inversion platform at 30 degrees

cryotherapy, for 20 minutes, water depth at 20 centimeters and temperature at 4±2°C, controlled by digital infrared thermometer (*MultTempâ*, Porto Alegre, RS, Brazil). The water was located below the attachment of electrodes for electromyography collection, so then they did not have to be removed. Immediately after cryotherapy application, a new electromyographic collection was performed, as previously described.

The aim was the electrical activity, in RMS (*Root Mean Square*), of the LG, TA and FL muscles of the dominant limb, submitted to an inversion movement of 30 degrees (pre- and post-application of cryotherapy). All data were normalized by the RMS peak at the moment of pre-cryotherapy, being considered, for that, the RMS after 0.2 seconds and after 1 second of platform opening. The statistical analysis was developed on the *software* SPSS® 15.0. The normality analysis used the Shapiro Wilk test and, for intra and intergroup comparisons, the Wilcoxon e Mann-Whitney U tests. The established significance level was established at 5%.

## RESULTS

The demographics of the sample are presented in Table 1. The comparison between the two groups (athletes and non-athletes) showed no difference in anthropometric variables.

The results of the RMS peak values for the LG, TA and FL muscles, of athletes and non-athletes, after the opening of the inversion platform, normalized by the pre-cryotherapy peak, are presented in Table 2. For the athletes group, the pre- and post-cryotherapy showed p=0.285 for the LG, p=0.017 for the TA and p=0.333 for the FL. For the non-athletes group, p=0.007, p=0.093 and p=0.013, for the same muscles, respectively.

The electromyographic response (RMS) collected up to 0.2 seconds after the opening of the inversion platform is demonstrated in Table 2. The statistical analysis has shown, for the LG, TA and FL muscles, the values  $p=0.24$ ,  $p=0.007$  e  $p=0.241$ , respectively, to the athletes; and  $p=0.037$ ,  $p=0.114$  e  $p=0.022$  to the non-athletes.

The RMS, collected up to one second after the opening of the inversion platform, did not indicate differences in the athletes group for the LG ( $p=0.241$ ), TA ( $p=0.074$ ) and FL ( $p=0.169$ ) muscles. However, for the non-athletes, there was a difference in the LG ( $p=0.007$ ) TA ( $p=0.007$ ) and FL ( $p=0.013$ ), after the application of cryoimmersion (Table 2).

At last, the comparison between athletes and non-athletes has established a significant difference for the RMS when analyzed up to 1 second after the platform opening, where the athletes showed lower recruitment to the pre-cryotherapy LG ( $p=0.01$ ) and for the pre- and post-cryotherapy TA muscle ( $p=0.05$ ). As for the remaining analysis, no differences were observed between the groups.

## DISCUSSION

The results evidence that, after cryoimmersion, there was a decrease in the electromyographic response for both athletes and non-athletes, which confirms the initial hypothesis of the study. These results may be explained by the amplitude reducing by the cryotherapy and

the increase of nerve action potential<sup>15</sup>, which triggers changes in the structure of the axon membrane and in the conductance of sodium and potassium channels, along with reduction of nervous conduction<sup>16</sup>, especially the sensitive nerves<sup>17</sup>. The related findings are confirmed by Khanmohammadi *et al.*<sup>18</sup>, who claim there is a linear relationship between the level of recruitment of the muscle spindle and the decreasing of the temperature. In addition to that, Bleakley *et al.*<sup>19</sup>, in a systematic review, suggest that after a twenty-minute-tissue cooling, the athletes may present a deficit in performance and therefore, need a progressive warm-up to return to physical activity.

The relation between cryotherapy and the decrease of motor control in basketball athletes should be further studied and discussed, since, in the attempt of minimizing tissue damage in acute ankle injuries, this feature is often used in the treatment of soft tissue injuries<sup>20</sup>. It is known the use of ice, compression and elevation, have been widely accepted as standard treatment in the control of pain and swelling, which facilitates the early activity of weight bearing and early return to sport. However, the effect of cryotherapy in motor control is not fully understood, it is believed it could affect the speed of nervous conduction, latency reflex, and the discharge rate of muscle spindle, resulting in an inadequate efferent response<sup>12</sup>.

Our results differ from those of Berg *et al.*<sup>12</sup> and Cordova *et al.*<sup>11</sup>, who did not observe differences in the amplitude nor the latency of the Fibular Longus muscle during the inversion movement after the cooling of the ankle articulation through ice bags. However, for Costello *et al.*<sup>21</sup>, physicians, physical therapists and physical trainers ought to be cautious as for the return of individuals to activities which demand proprioceptive components, immediately after a cryotherapy treatment. Also, Uchio *et al.*<sup>10</sup> report the need for concern about the return of the athletes to exercises after cryotherapy,

Table 1. Average and standard deviation of age and anthropometric data of college basketball athletes and non-athletes.  $n=10$

	Athletes mean $\pm$ SD	Non-athletes mean $\pm$ SD	p-value
Age (years)	24.1 $\pm$ 6.93	21.3 $\pm$ 1.55	0.14
Mass (kg)	84.6 $\pm$ 8.24	74.86 $\pm$ 13.63	0.07
Height (cm)	181.44 $\pm$ 8.47	175.8 $\pm$ 5.02	0.16
BMI (kg/m <sup>2</sup> )	25.94 $\pm$ 2.02	23.69 $\pm$ 3.77	0.13

SD: standard deviation

Table 2. *Root Mean Square* values of pre- and post-cryoimmersion, expressed in percentage (median, minimum and maximum values), normalized by the *Root Mean Square* peak in the pre-cryoimmersion on peak times, 0.2 s and 1.0 s after opening the platform inversion, Lateral Gastrocnemius muscles, Tibialis Anterior and Fibular Longus, in athletes and non-athletes groups.  $n=10$

		Athletes			Non-athletes		
		Muscles			Muscles		
		LG	TA	FL	LG	TA	FL
RMS (peak)	Pre	100	100	100	100	100	100
	Post	51 (15/220)	59 (7/106)*	58 (9/252)	70 (38/104)*	69 (45/216)	69 (53/117)*
RMS (0.2 s)	Pre	79 (46/85)	74 (60/79)	76 (44/84)	82 (31/89)	76 (64/85)	73 (50/83)
	Post	41 (13/116)	43 (5/71)*	49 (6/205)	57 (30/81)*	53 (34/151)	47 (37/84)*
RMS (1.0 s)	Pre	44 (38/66) <sup>#</sup>	42 (38/58) <sup>#</sup>	50 (40/62)	54 (39/73)	52 (41/94)	53 (41/73)
	post	28 (11/131)	24 (3/116) <sup>#</sup>	35 (5/101)	47 (25/62)*	42 (22/59)*	43 (34/66)*

\* $p<0.05$  compared to respective pre and <sup>#</sup> $p<0.05$  compared to the non-athlete group. LG: lateral gastrocnemius; TA: tibialis anterior; FL: fibular longus; RMS: *Root Mean Square*

considering the results are contradictory, which justifies the need of further investigations.

This study also aimed to compare the effects of cryoimmersion in athletes and non-athletes. The initial hypothesis was that the basketball sportive training, due to the jumping, the physical contact and the fast changing of directions involved, would provide the athletes with better motor control and, this way, cryotherapy would be less effective on the ankle, when compared to the non-athlete individuals. In this sense, Kirkendall and Garret Junior<sup>22</sup> claim one of the benefits of sportive training, according to the specificity of each Sport, is the best synchronization of the activation of motor units, which leads to increased motor control. Also, Cadore *et al.*<sup>23</sup> observed a significant increase in the amplitude of the electromyographic signal after training.

However, the hypothesis has not been confirmed when analyzed the peak of RMS and the RMS in up to 0.2 seconds after the opening of the platform, for it has evidenced the equality of groups. Opposed to that, when analyzed the RMS up to 1 second after the opening of the platform, the athletes presented lower recruitment levels to the LG and the TA muscles, before and after the application of cryoimmersion. Justifying the results of the present study, Bueno *et al.*<sup>24</sup> state the specific training for a sport may result in different neuromuscular adaptations, according to the received stimulus and thus, we believe that such adaptations may be superior to the motor control deficit caused by cryoimmersion.

There are some limitations which ought to be recognized and discussed, concerning the present study. For the analysis of the electromyographic response, after ankle inversion, the sample consisted of athletes and active individuals without any ankle injury, for the authors understand that the inversion platform could exacerbate the pain and/or injuries in individuals with any ankle alterations. Furthermore, the possibility of a control group being submitted to immersion in water at room temperature or at rest should be considered to ensure the effects of cryoimmersion in neuromuscular response of the ankle.

## CONCLUSION

In a general way, the non-athletes group presented greater alterations in the electromyographic signal port

cryoimmersion, with lower recruitment of the LG, TA and FL muscles; while the athletes, after cooling down, have established lower values only to the TA. As a clinical contribution, it is pointed out that after the use of cryotherapy on the ankle, one should be careful with intense exercises, due to lower motor unit recruitment.

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