

Electromyographic activity of the rectus femoris muscles following the knee joint cooling with different cooling agents

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ABSTRACT

Introduction: Local cryotherapy (LC) is a common physical treatment often used in the area of joints. However, it has not been assessed whether the procedure performed within the joint may significantly affect the function of the muscles in its close vicinity. The aim of the present study was to assess the impact of the most commonly used clinical cooling agents – liquid nitrogen (LN), cold air (CA), and an ice bag (IB) – applied to the knee joint on the bioelectrical activity of the rectus femoris muscle, as assessed by surface electromyography (sEMG).

Materials and methods: The study population consisted of 12 healthy women (mean age: 25.33 years) and 11 healthy men (mean age: 28 years). Each participant reported to the study center 3 times. Study procedures included a one-time body composition analysis, measurement of skinfold thickness above the knee, completion of the International Physical Activity Questionnaire (IPAQ), and 3 LC sessions. Each visit began with sEMG recordings

of the right and left rectus femoris muscles in a free-standing position. One of the 3 cooling agents was then applied to the right knee joint only (for 3 min), and sEMG was repeated after 20 min. The rectus femoris muscle of both the exposed and unexposed lower limbs was evaluated.

Results: There was no significant effect of the LC procedure on the root mean square amplitude (ARMS) of the sEMG signal after LN ($p = 0.887$), CA ($p = 0.559$), or IB ($p = 0.999$) stimulation. There was also no significant change in the ARMS value of the rectus femoris muscle in the unstimulated limb.

Conclusion: Regardless of the cooling agent used, cooling the knee joint does not significantly affect the spontaneous bioelectric activity of the rectus femoris muscle in either the treated or the contralateral limb.

Keywords: sEMG; local cryotherapy; cooling agents; liquid nitrogen; cold air; ice bag.

INTRODUCTION

Joint cooling is a standard physical procedure (local cryotherapy – LC) used in the rehabilitation of the musculoskeletal system to achieve analgesic, anti-inflammatory, anti-edematous, and decongestive effects. The therapeutic effects of LC are obtained by temporarily disrupting the thermal homeostasis of the treated area and triggering a series of thermoregulatory reactions, which, however, depend on the type of cooling agent used and the duration of treatment [1, 2, 3]. Despite an increasing number of studies, the available literature shows significant variability in both the type of coolant and the duration of its application in LC procedures. The most commonly used clinical cooling methods include bagged ice, ice packs, compressive cryotherapy devices, and cooling gases such as cold air (CA), carbon dioxide microcrystals, and liquid nitrogen (LN) [4, 5, 6].

The knee joint plays a crucial role in lower limb biomechanics, with its function closely linked to the surrounding muscles. Knee joint cooling, commonly employed as a therapeutic intervention to alleviate pain and inflammation [7, 8], may influence not only the joint itself but also the associated muscles. The hypothesis that knee joint cooling may affect the bioelectrical activity of muscles not directly exposed to cooling arises from several key observations. The knee joint is innervated by nerves that also supply adjacent muscles, and cooling of

the joint can alter the signaling properties of these nerves, potentially impacting muscle activity. Research has shown that joint cooling can modify proprioceptive feedback, which may in turn alter muscle activation patterns, even in muscles not directly exposed to the cold.

The rectus femoris muscle, part of the quadriceps group, is anatomically and functionally linked to the knee joint. The tendon of this muscle, known as the patellar tendon, crosses the knee joint, indicating a direct biomechanical relationship. Therefore, knee joint cooling may influence the rectus femoris muscle through changes in joint mechanics or tendon properties [9, 10, 11, 12, 13]. These premises provide a strong basis for hypothesizing that knee joint cooling may influence the bioelectrical activity of muscles not directly exposed to the cooling process.

Understanding these interactions is crucial for optimizing therapeutic strategies and improving rehabilitation outcomes for patients with knee joint injuries or conditions. If knee joint cooling is found to significantly affect the bioelectrical activity of the rectus femoris muscle, it may suggest the need to modify cooling techniques to avoid undesirable side effects such as muscle weakness. This could lead to the development of more precise therapeutic protocols that minimize risk and maximize benefits for the patient. Conversely, if knee joint cooling does not significantly impact the bioelectrical activity of surrounding muscles, it may allow for more liberal application of this

technique without concerns about adverse effects on muscles not directly exposed to the cooling.

The LC procedure performed on a joint may also potentially impact the function of muscles in its close vicinity. One method that provides non-invasive insight into neuromuscular system behavior, including myoelectric features of neuromuscular activation associated with spontaneous muscle activity, is surface electromyography (sEMG). Surface electromyography enables non-invasive monitoring of muscle bioelectrical activity using electrodes placed on the skin. This method is particularly useful for assessing muscle function under various conditions and during different activities.

The sEMG signal represents a time-varying distribution of electrical voltage recorded on the skin surface as a result of muscle activity. It reflects the temporal and spatial summation of action potentials from all active motor units within the electrode detection area. Different types of sEMG exist, varying in electrode configuration, signal recording methods, and specific applications. Based on the number and configuration of electrodes, sEMG can be classified into single-channel sEMG, multi-channel sEMG, and electrode array sEMG (high-density sEMG, HD-sEMG). The electromyographic parameter that determines the average voltage generated by muscle units is signal amplitude, which, after applying the root mean square (RMS) algorithm, is referred to as spontaneous root mean square amplitude (A_{RMS}) and measured in microvolts (μV). Additionally, the frequency components of the signal provide information about muscle activity type and fatigue, while muscle activation timing analysis helps assess motor coordination [14, 15, 16, 17, 18].

Traditionally, sEMG has been used to assess muscle fatigue, denervation, reinnervation, muscle coordination, load distribution, and spasticity, helping to prevent disorders and evaluate treatment effectiveness. In recent years, its applications have expanded to new fields, including: obstetrics, occupational medicine, medical art, neurorehabilitation, ergonomics, preventive medicine, aging research, veterinary medicine, prosthetic control, robotics, and the development of human-machine interfaces [19, 20].

Surface electromyography has previously been used to evaluate neuromuscular function after various types of LC, including: cold compresses [21], computer-controlled cooling devices [22], ice massage [23], and LN applications [24]. However, existing studies have primarily focused on assessing the impact of LC on directly stimulated muscles while ignoring adjacent and contralateral areas [24]. Direct muscle cooling has been shown to slow nerve conduction, reduce receptor potential release, and decrease neuromuscular spindle activity, thereby affecting the activity of exposed muscles. However, it remains unclear whether similar changes in spontaneous activity occur in muscles when the treatment is focused on the joint area.

From both a research and clinical perspective, it is valuable to understand the potential impact of LC on the muscular system when joint therapy is performed without directly exposing the muscles to cooling [19, 20]. Therefore, the aim of this study was to assess the effect of the most commonly used clinical cooling

agents – LN, CA, and an ice bag (IB) – applied to the knee joint on the activity of the rectus femoris muscle, as evaluated by sEMG.

MATERIALS AND METHODS

Participants

The study population consisted of healthy subjects between the ages of 20–40 years. The inclusion criteria were: age 20–40 years, good health, and no contraindications to cryotherapy treatments. Exclusion criteria included the presence of metabolic disease, chronic cardiovascular disease, inflammatory musculoskeletal conditions, and a history of lower extremity trauma in the previous 2 years. Of the 31 volunteers, 23 were enrolled, including 12 women and 11 men, with a mean age of 27 ± 4.56 years (mean body height: 1.72 ± 0.08 m; mean body mass: 72.82 ± 14.27 kg). Subjects were fully informed of the purpose and procedures of the study. All qualified volunteers provided written consent to participate in accordance with the Declaration of Helsinki.

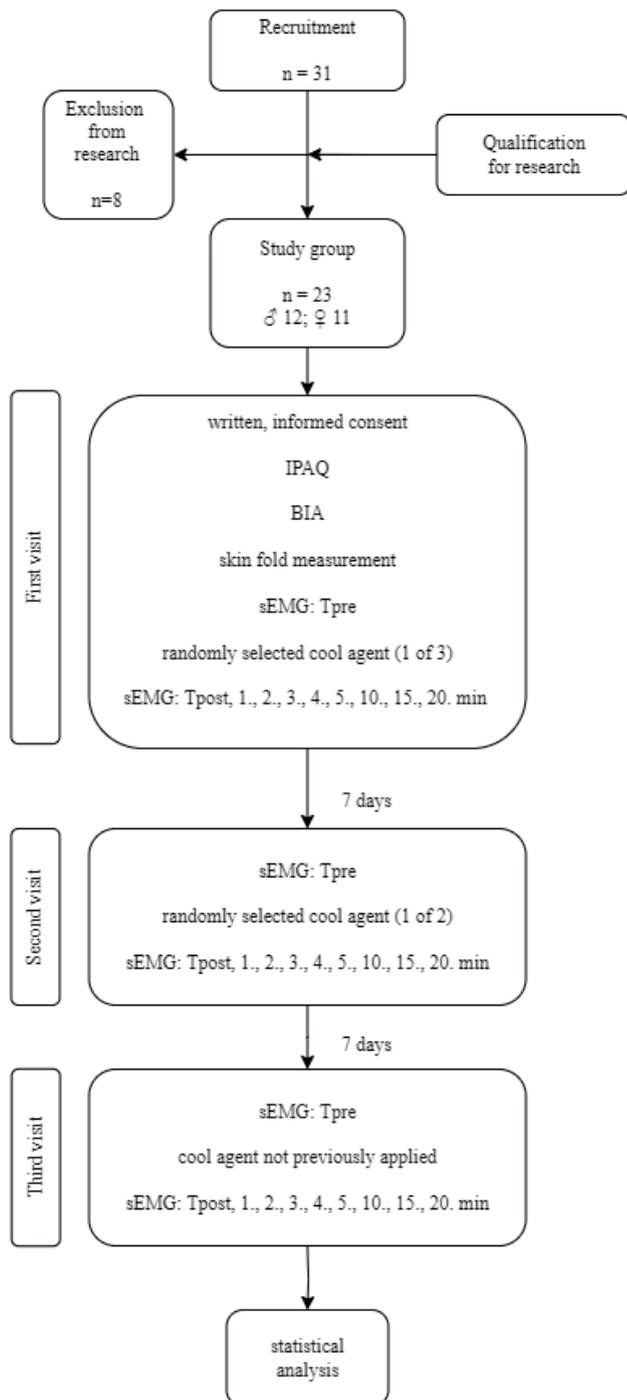
The study was conducted at the Centre for Research on the Effects of Cryogenic Temperatures on the Human Body (Chair and Department of Functional Diagnostics and Physical Medicine, Pomeranian Medical University in Szczecin) between July and September 2020. The study was approved by the Bioethics Committee of the Pomeranian Medical University in Szczecin (No. KB-0012/146/16). The course and sequence of research procedures are presented schematically in Figure 1.

Research procedures

On the first study visit, after obtaining written informed consent, physical activity levels were assessed using the Polish version of the International Physical Activity Questionnaire (IPAQ) [25]. Next, body composition analysis was performed using bioelectrical impedance analysis (BIA) with an ACCUNIQ BC380 device (SELVAS HEALTHCARE, Korea), following standard procedures. Above-knee skinfold thickness was then measured 3 cm from the base of the patella using a Harpenden Skinfold Caliper (England).

Each visit began with sEMG recordings of the right and left rectus femoris muscles. Electrodes were placed according to the surface electromyography for non-invasive assessment of muscles (SENIAM) protocol: at a distance of 50% along the line from the anterior superior iliac spine to the top of the patella, longitudinally on the belly of the rectus femoris muscle (2 electrodes per limb, 20 mm apart). The reference electrode was positioned on the ankle. Before electrode placement, the skin was lightly abraded. Noraxon Ag/AgCl dual electrodes were used in the study.

Following electrode placement, the apparatus was connected, and a 5-minute stabilization period was observed to ensure stable electrical conditions. An impedance test was then conducted using an electrode impedance tester (EMG NORAXON INC., USA). If impedance was within the range of 1–5 K Ω , electromyographic signal recording was initiated. During recording, subjects stood in a relaxed position with feet parallel and hip-width apart. One of the 3 cooling agents was then applied to the anterior side of the left knee joint for 3 min according to the



IPAQ – International Physical Activity Questionnaire; BIA – bioelectrical impedance analysis; sEMG – surface electromyography

FIGURE 1. The course and sequence of research procedures

procedure described below. Surface electromyography measurements continued for 20 min following the cooling procedure.

The electromyographic signal was recorded using a 4-channel Myotrace 400 Noraxon instrument, with a sampling rate of 1500 Hz and 16-bit resolution. Mathematical analysis of electromyograms was performed using MyoResearch XP Master Edition software (v. 1.08.27), applying Standard Amplitude protocols. Signals were filtered to remove motion artifacts and

high-frequency noise (band-pass filters with cutoff frequencies of 20 and 500 Hz). The raw sEMG recordings were then rectified and smoothed using a RMS calculation over a 50 ms time window. The recorded sEMG data were analyzed for changes in the A_{RMS} value. To determine the A_{RMS} , 30-second segments of the sEMG signal were rectified, and an envelope was created using the RMS calculation algorithm.

Each participant underwent 3 sessions, each separated by a 7-day washout period, during which a different cooling agent was applied. The order of cooling agent application was randomized, and participants were blinded to the cooling agent used.

Ice application to the knee joint was performed with IB (MUELLER, 23 cm), which was applied directly to the skin surface of the knee joint for 3 min. Ice bag was filled with ice cubes with an average weight of 1100 g. The application of CA was performed by reducing the distance from the skin surface to 2–5 cm and by using a ZIMMER CRYO 6 device (Zimmer MedizinSysteme GmbH, Hamburg, Germany, 2013). In the Zimmer Cryo6 device, CA is generated by cooling the ambient air in a closed cooling circuit (the temperature at the nozzle outlet specified by the manufacturer is ca. -30°C). A blowing intensity of 9 was used (1000 L/min, nozzle diameter 15 mm). The procedure, in accordance with current practice, was performed for 3 min. The application of LN was performed with a KRIOMEDPOL KRIOPOL R11 device (Kriomedpol, Stare Babice, Poland). The distance of the nozzle from the skin was 10–15 cm, with circular movements around the patella. In the device used, vapors are produced by heating LN with a heating element in the device's cylinder (temperature of the gas stream at the nozzle outlet specified by the manufacturer -160°C , LN consumption 0.15 kg/min in continuous operation). The procedure, in accordance with current practice, was performed for 3 min.

Consecutive appointments were separated by a 7-day break. The order of the applied cooling agents was randomized and the volunteer would not be informed as to the name of the applied cooling agent. None of the participants in this study reported a negative reaction to the applied cooling agents.

Statistical analysis of the results was performed using Statistica 13.3 software (Statistica PL, StatSoft, Kraków, Poland). Data distribution was examined using the Shapiro–Wilk test and a data scatter plot. In the case of normal data distribution, the characteristics of the studied variables were presented in the form of arithmetic mean and standard deviation, and in the case of variables with a non-normal distribution, in the form of median, minimum, and maximum values. The Student's t-test was used to test the significance of differences between pairs of independent variables with a normal distribution (anthropometric variables and body composition). For non-parametric variables, U-Mann–Whitney tests (IPAQ, A_{RMS}) were used. Wilcoxon signed-rank test was used to compare A_{RMS} values between exposed and unexposed limbs at the same observation time points.

A power analysis of the test was performed to determine the minimum detectable difference (MDD) between A_{RMS} values in the exposed and unexposed limb. As the data for the same individual in both limbs were correlated, the formula for dependent sample tests was used for the calculations. Assuming

a significance level of $\alpha = 0.05$ and a test power of $1-\beta = 0.80$, the MDD in A_{RMS} values between limbs was found to be $1.37 \mu V$.

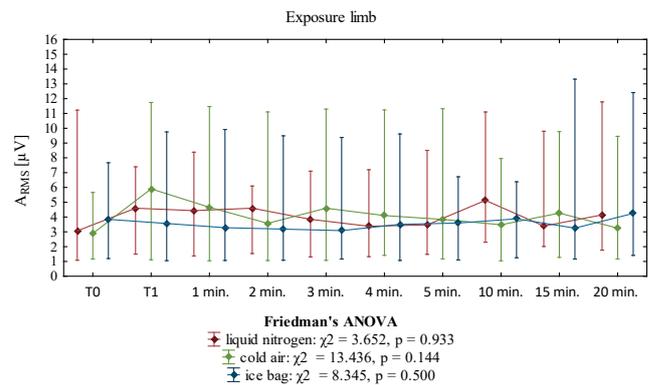
The Friedman's ANOVA test was used to compare the mean A_{RMS} values recorded before and after the application of the 3 types of cooling agents at the same time points. Friedman's ANOVA test was also used to evaluate changes in A_{RMS} values over time after exposure to each of the 3 cooling agents.

RESULTS

The study group consisted of 11 women and 12 men with an average age of 27 years. Men had higher average values of fat-free mass, total body water, and lean body mass compared to women, and these differences were statistically significant ($p = 0.001$). All subjects were characterized by satisfactory physical activity according to IPAQ (>600 metabolic equivalent of task – MET). There were no statistically significant differences in body mass index, thickness of fatty acid folds, and physical activity according to IPAQ, therefore, it was decided to analyze the entire group without division by gender. Detailed characteristics of the study group in terms of age, composition of action, and action enabling use are presented in Table 1.

The baseline A_{RMS} value on all 3 days of exposure was within the so-called "bioelectric silence" (<25 μV), confirming that the position adopted during the examination ensured relaxation of the assessed muscles of both the stimulated and unstimulated lower limbs. After exposure, there were no statistically significant changes in the median value of A_{RMS} , regardless of the cooling agent used (Friedman's ANOVA: LN: $\chi^2 = 3.652$,

$p = 0.933$; CA: $\chi^2 = 13.436$, $p = 0.144$; IB: $\chi^2 = 8.345$, $p = 0.500$) during the entire 20-minute observation period (Fig. 2). Similarly, in the case of the contralateral leg, no statistically significant changes in the median A_{RMS} value were observed, regardless of the cooling agent used (Friedman's ANOVA: LN: $\chi^2 = 14.299$, $p = 0.112$; CA: $\chi^2 = 13.745$, $p = 0.132$; IB: $\chi^2 = 5.364$, $p = 0.802$) during the entire 20-minute observation period (Fig. 3). The Friedman ANOVA test was used to compare the A_{RMS} values recorded before and after the application of the types of cooling measures at the same time points. There were no significant differences between the A_{RMS} values recorded after exposure to the cooling agents tested in either the exposed ($p > 0.05$) or unexposed limb ($p > 0.05$) – Figures 2 and 3.



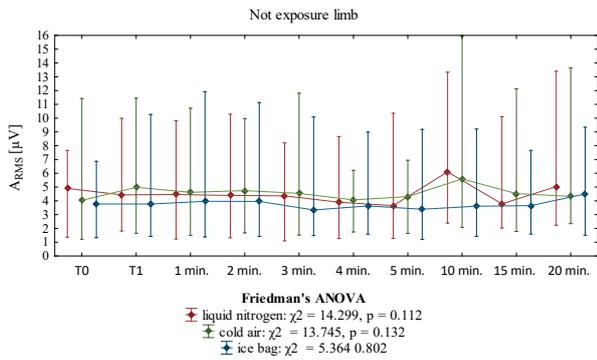
A_{RMS} – root mean square amplitude; \square – Q25–Q75; \blacksquare – median value

FIGURE 2. Change in the median A_{RMS} value recorded from the rectus femoris muscle of the exposed limb after 3-minute application of 3 different cooling agents to the knee joint

TABLE 1. Characteristics and initial surface electromyography values of the study group with regard to gender

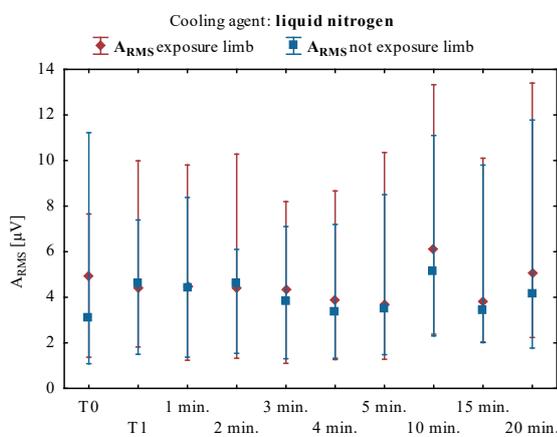
Variables	Study group (n = 23)		Women (n = 11)		Men (n = 12)		Women vs. men
	mean/*median	$\pm SD$ / *(min.–max.)	mea/ *median	$\pm SD$ / *(min.–max.)	mean/*median	$\pm SD$ / *(min.–max.)	p-value test t/ *U-Mann-Whitney
Age (years)	26.67	4.56	25.33	4.87	28.00	4.06	0.225
BMI (kg/m ²)	24.51	3.80	23.91	5.12	25.05	2.29	0.557
FFM (kg)	49.73	11.95	40.78	6.62	57.69	9.78	0.001
TBW (kg)	38.99	9.13	32.20	5.29	45.03	7.40	0.001
LBM (kg)	53.27	12.50	44.00	7.24	61.51	10.21	0.001
SMM (kg)	29.85	7.17	24.48	3.99	34.62	5.86	0.001
SF _{NEL} (mm)	17.12	5.29	18.90	2.22	14.71	5.94	0.106
SF _{EL} (mm)	16.81	4.82	18.96	2.88	15.29	6.68	0.206
IPAQ (MET)*	1466.50	(99–8238)	1466.50	(693–6279)	1278.00	(99–8238)	0.862
To – $A_{RMS,NEL}$ (μV)*	4.52	(1.38–14.4)	4.29	(1.38–14.40)	4.75	(2.62–11.92)	0.536
To – $A_{RMS,EL}$ (μV)*	3.59	(1.86–11.38)	3.59	(1.86–6.26)	3.91	(2.24–11.39)	0.216

BMI – body mass index; FFM – fat free mass; TBW – total body water; LBM – lean body mass; SMM – skeletal muscle mass; SF_{NEL} – skinfold of the non-exposed limb; SF_{EL} – skinfold of the exposed limb; IPAQ – International Physical Activity Questionnaire; MET – metabolic equivalent of task, To – $A_{RMS,NEL}$ – root mean square amplitude of the non-exposed rectus femoris before exposure; To – $A_{RMS,EL}$ – root mean square amplitude of the exposed rectus femoris; SD – standard deviation *median (min.–max.) or p value for U-Mann-Whitney test



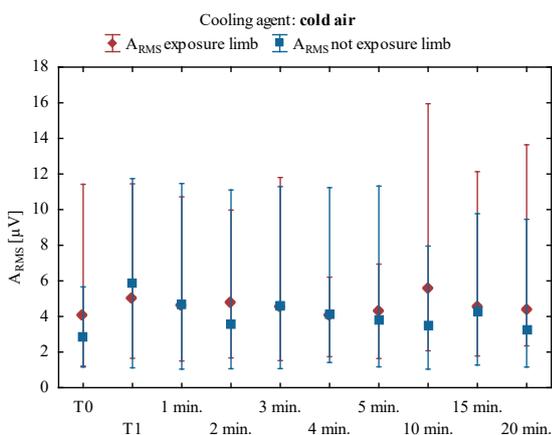
A_{RMS} – root mean square amplitude; \square – Q25–Q75; \blacklozenge – median value

FIGURE 3. Change in the median A_{RMS} value recorded from the rectus femoris muscle of the not exposed limb after 3-minute application of 3 different cooling agents to the knee joint



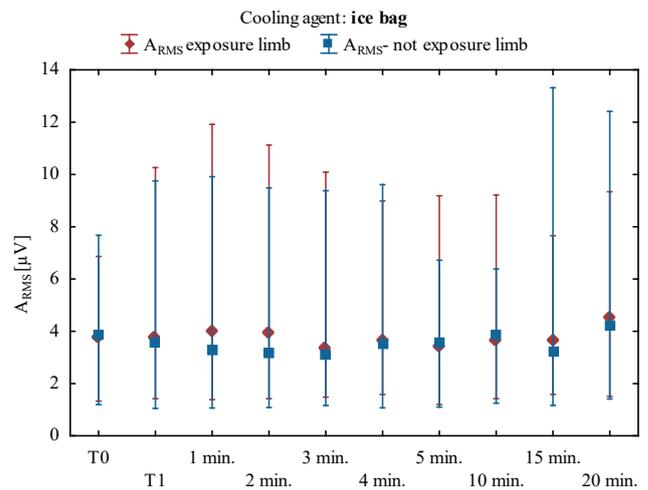
A_{RMS} – root mean square amplitude; \square – Q25–Q75; \blacklozenge – median value
No statistically significant differences were observed between the exposed and non-exposed limb at any time point (Wilcoxon signed-rank test, $p > 0.05$ for all comparisons).

FIGURE 4. Comparison of median A_{RMS} values recorded from the rectus femoris muscle of the exposed and unexposed limb after a 3-minute nitrogen application to the knee joint



A_{RMS} – root mean square amplitude; \square – Q25–Q75; \blacklozenge – median value
No statistically significant differences were observed between the exposed and non-exposed limb at any time point (Wilcoxon signed-rank test, $p > 0.05$ for all comparisons).

FIGURE 5. Comparison of median A_{RMS} values recorded from the rectus femoris muscle of the exposed and unexposed limb after a 3-minute cold air application to the knee joint



A_{RMS} – root mean square amplitude; \square – Q25–Q75; \blacklozenge – median value
No statistically significant differences were observed between the exposed and non-exposed limb at any time point (Wilcoxon signed-rank test, $p > 0.05$ for all comparisons).

FIGURE 6. Comparison of median A_{RMS} values recorded from the rectus femoris muscle of the exposed and unexposed limb after a 3-minute ice bag application to the knee joint

In the next stage of analysis, the occurrence of differences between the exposed and unexposed limb was assessed. No contralateral reaction (significant change in A_{RMS} value) was confirmed in the unexposed limb following exposure of the exposed limb to LN, IB, and CA – Figures 4, 5, 6 (Wilcoxon signed-rank test, $p > 0.05$).

DISCUSSION

In the study, we assessed the impact of LC treatment in the area of the knee joint on the characteristics of sEMG signals recorded from the rectus femoris muscles during standing, using the 3 most clinically used cooling agents, i.e., CA, LN, and IB. We assessed rectus femoris activity for 20 min after the LC procedure on both the stimulated and contralateral limbs. To the authors' knowledge, this is the first study to compare spontaneous muscle bioelectrical activity after stimulation of the LN, CA, and IB of the joint area. The results of the presented research will complement the knowledge on the possible impact of joint cryotherapy on the neuromuscular functions of the muscles in their vicinity.

A healthy muscle, even when fully relaxed, has a certain bioelectrical tension. Therefore, the resting electromyogram should properly have an amplitude of not more than 25 μV , the so-called "electrical silence", which is an indicator of normal myoelectric activity at rest. Electromyograms recorded during activity are characterized by a large amplitude range from several dozen to several hundred μV [14, 15, 25, 26, 27, 28]. The A_{RMS} value of the resting signal may fluctuate slightly during the day, reaching its peak in the afternoon, or remain without significant daily changes. In the presented studies, signals from the rectus femoris muscle recorded during free standing before

LC were characterized by RMS amplitude values typical of bioelectric silence (median: $T_0 - A_{RMS_NEL}$: 4.52 μ V; $T_0 - A_{RMS_EL}$: 3.59 μ V), which are observed during muscle relaxation (Tab. 1).

Lowering the temperature of the joint area due to LC triggers a number of mechanisms, including reducing the sensitivity and firing rate of receptors and decreasing nerve conduction velocity (NCV). It has been shown that direct muscle cooling reduces nerve conduction speed and receptor potential release, lowers neuromuscular spindle activity, reduces adenosine triphosphate (ATP) hydrolysis, and impairs calcium release and uptake in muscles. Additionally, according to van't Hoff's rule, lowering the tissue temperature by 10°C results in a twofold reduction in the rate of chemical reactions occurring in the tissue [29]. Previous analyses have shown that a 3-minute exposure to LN, IB, and CA causes a decrease in the skin temperature of the knee joint area by an average of 6.76–10.11°C. One minute after the LC procedure, the temperature of the stimulated area begins to increase, with the most significant rise occurring between 5–10 min post-exposure. Between 10–20 min post-exposure, the temperature of the knee joint area continues to rise, approaching pre-LC values [6]. During this observation period (1–20 min post-exposure), the electromyographic activity of the rectus femoris muscle in the exposed limb showed slight fluctuations, regardless of the cooling agent used, but these changes were not statistically significant (Fig. 2).

The lack of change in the electromyographic activity of the rectus femoris muscle may be due to the fact that it was not directly exposed to LC or that the applied procedures cooled the knee joint area insufficiently or for too short a duration to impact the activity of the assessed muscle. In contrast, studies involving direct muscle cooling have shown a significant increase in A_{RMS} values recorded from the radial extensor muscles of the wrist, both in individuals with enthesopathy and in healthy volunteers [24].

The available literature lacks studies evaluating the impact of LC applied to the joint area on sEMG signals recorded from lower limb muscles during standing. Existing studies have focused on spontaneous 24-hour muscle activity [26], monitoring trigger point activity in young individuals [30], assessing the effects of spinal manipulative therapy in patients with low back pain [31], and evaluating neck muscle dysfunction in office workers [27]. However, in studies where cooling was applied directly to the muscles, significant changes in electromyographic activity were observed [24].

There are numerous studies on the effects of cooling on the sEMG signal recorded during voluntary contraction. Some studies report an increase [32, 33, 34], while others indicate a decrease [33, 35] in the sEMG signal amplitude. However, due to differences in study protocols and the nature of assessed activities, these findings cannot be directly compared with the present study results.

The literature provides many examples showing that unilateral interventions can produce bilateral effects. For instance, unilateral strength training has been shown to increase strength not only in the trained muscle but also in the homologous muscle of the opposite limb [36, 37]. This cross-transfer

effect has been observed in both small and large limb muscles and in response to different types of exercise, as well as after unilateral electrical muscle stimulation [38, 39, 40]. However, no contralateral response was observed in the present study. Analysis of A_{RMS} values showed no significant differences between the stimulated and non-stimulated limb rectus muscles during the 20-minute observation period (Fig. 4, 5, 6).

LIMITATIONS OF THE STUDY

The limitations of our study include the use of the standing position for measurements. Although the standing position is not a resting posture, it has been used in other similar studies, which influenced our decision to adopt this methodology. The standing position can affect results by increasing muscle activity and hemodynamic variability, potentially leading to differences in A_{RMS} values compared to measurements taken in sitting or lying positions. Our decision to use the standing position was motivated by the goal of obtaining results that are more representative of everyday activities. However, due to the potential impact of this position on the results, future studies should consider comparing measurements taken in different body positions to better understand the influence of posture on A_{RMS} values.

Another limitation of our study is that we did not examine muscles other than the rectus femoris muscle in both lower extremities, even though the area affected by cold stimulation may be broader. We chose the rectus femoris muscle as the index muscle for potential responses to knee joint cooling due to its direct proximity to the target knee joint and the fact that its tendon (patellar tendon) runs directly over the joint. By focusing on the rectus femoris muscle, we sought to provide a precise and consistent measurement of the muscle's bioelectrical response to knee joint cooling. However, future studies should consider expanding the range of muscles studied to fully understand the effects of cold stimulation on the activity of surrounding muscles.

CONCLUSIONS

1. Cooling the knee joint does not significantly affect the spontaneous bioelectrical activity of the rectus femoris muscle observed up to 20 min after the end of exposure.
2. The LC procedure performed on the knee joint does not influence the spontaneous bioelectrical activity of muscles during standing, as assessed by sEMG, in either the stimulated or contralateral limb.
3. The type of cooling agent used, despite differences in temperature (LN, IB, CA) for joint area stimulation, does not affect the spontaneous bioelectrical activity of the muscles during standing.

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