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Evaluation of changes in selected skin parameters under the influence of extremely low temperature

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ABSTRACT

The aim of the work was to evaluate changes in selected skin parameters under the influence of low temperature. The tests were conducted on a group of 20 women using whole-body cryotherapy. The average age of participants was 58.7 ± 7.54 years; the average body weight 77.84 ± 16.01 kg, the mean BMI 30.14 ± 5.81, and the average body height 160.7 ± 6.48 cm. The tested parameters included hydration, lubrication, temperature, and pH of the skin. The skin measurements were made on the first and tenth treatment days, before and after leaving the whole-body cryo-chamber. To assess the data collected before and after the experiment, the measurement taken at each time point were compared. After a series of ten treatment sessions, the greatest decrease was observed in skin hydration and skin temperature. No significant differences were noted for lubrication and skin pH. The analysis showed statistically significant differences in skin parameters between all measurement locations; the upper and lower limbs responded more significantly to cold than other parts of the body. It was also found that the facial skin was more lubricated and hydrated compared to other measuring locations. We conclude that varies skin parts respond differently to low temperature. Cryotherapy causes a significant decrease in temperature and hydration of the skin whereas differences in pH and lubrication of the skin remain insignificant.

1. Introduction

The skin is a very important organ of the organism that performs many important functions of the organism as a whole. They can be divided into protective (passive) as well as secretory and sensory (active) functions [21]. Thanks to the skin, we are in close and constant contact with both the external and internal environment [19]. The structure of the skin is complex, with a three-layer structure that is formed by the epidermis, dermis and subcutaneous tissue. Such construction helps to ensure its durability, continuity and elasticity [21]. The skin is involved in the process thermoregulation. Thanks to physiological processes, it is possible to maintain the body's thermal homeostasis. The factors allowing for maintaining the relative thermal balance are hairiness and fat tissue. They are insulators that do not allow excessive heat loss. The amount of heat delivered or received is influenced by the microcirculation of the skin, which consists of the tension of the vessel walls and the volume of the vascular bed [8].

Treating the human body with low temperatures causes many beneficial physiological and biochemical reactions in the body, used in the treatment process. This factor is widely applied in medicine, physiotherapy, sport, and biological regeneration, as well as in dermatology and cosmetology [17]. Cryotherapy due to its non-invasive nature is increasingly used in aesthetic medicine in order to care for the body and the appearance of the skin. The effects that appear after the application of low temperature on the human skin are: improvement of skin tone, slowing down of the ageing process, the overall effect of loosening of the body, relaxation. Low temperatures are also used to improve the firmness and hydration of the skin, reduce pain perception during other treatments, eliminate skin changes, and reduce excessive fat tissue [22].

Literature review reveals newer possibilities of using low temperatures in cosmetology and dermatology. There are objective and subjective reports occurring about the positive impact of this factor. Thanks to the easy methodology of conducting the procedure and its safe nature, it is possible to use cryotherapy in order to alleviate shallowly positioned vascular changes and fight cellulite [12,20]. It has also been proven that cryotherapy influences the increase of skin hydration level and is a well-tolerated treatment for patients [14]. However, there is not much research work that accurately describes the methodology of treatments and explains the effect of the therapy with cold on the human skin [18]. There are works published that describe the use of individual probes for testing skin parameters [2,15]. On the other hand,

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it is difficult to find the results of reliable scientific studies analysing the influence of extremely low temperatures on the human skin, especially in terms of changes in such parameters as pH, temperature, hydration, sebum.

The aim of the work was to analyse selected skin parameters: temperature, pH of the skin, the level of skin surface hydration and the level of sebum on the surface of the skin in various research areas. The changes in these parameters were assessed under the influence of low temperature in the whole-body cryogenic chamber.

2. Materials and methods

The research was carried out on a group of 20 women using whole-body cryotherapy in the Cryotherapy Laboratory run by the Creator Prevention and Rehabilitation Center, at the Faculty of Physiotherapy at the University School of Physical Education in Wrocław. Treatments with the use of the cold were ordered by the attending physician as part of the treatment of patients with motor dysfunctions. These diseases did not directly affect the condition of the skin, which was subjected to extremely low temperatures each time. Participants with contra-indications for whole-body cryotherapy such as selected cardiovascular diseases, venous insufficiency, cancer, thyroid diseases, inflammatory lesions, and wounds were not enrolled. Patients having disorders that might affect the skin temperature or the measurement of skin parameters such as telangiectases, skin injuries, and any other skin lesions were not included either.

All persons underwent 10 cryo-stimulation procedures in the cryochamber, for two weeks, from Monday to Friday. Each time the procedure consisted in the subjects being examined in the vestibule of the chamber, at a temperature of −60 °C for about 1 min, after which they moved to the proper chamber for up to 3 min at a temperature of −130 °C.

Each person was offered to participate in the testing of the skin condition, to which they gave their written consent. They were accurately informed about the course and duration of the measurements. The study was approved by the Senate Committee for Research Ethics at the University of Physical Education on 28 June 2016.

2.1. Research methods

All skin parameters were measured on intact healthy skin.

To test the pH of the skin, Skin-pH-Meter PH 905 was used in which the connection electrode is located. Both the H + glass ion selective electrode and the additional reference electrode are placed in one housing. The test result is given in the pH values, in the scale of acidity and basicity of aqueous solutions of chemical compounds. The glass ion-selective electrode is filled with a mercury solution/mercuric chloride or silver solution/silver chloride, while the reference electrode in contact with the test skin is filled with electrolyte, which allows the transfer of ions on the skin to the internal buffer solution. The electrode is connected to the probe holder containing the measuring electronics. The probe electronics allow for a very fast, 1-s measurement, eliminating the effects of occlusion. The probe head is flat to measure the surface of the skin optimally.

Testing the amount of secreted sebum on the surface of the skin was performed with the Sebumeter SM 815 probe that allows for the repetitive and accurate determination of the level of sebum on the surface of the skin, as well as on the scalp and hair. The measurement is based on the photometry of the spot lubricant. It consists in applying the Sebumetra matt tape to the skin for 30 s. When the tape comes in contact with the skin, it becomes transparent in relation to the sebum of the measuring surface. Then, the tape is placed in the inlet of the device, and the transparency is measured by means of a photocell. The transmission of light is illustrated by the content of sebum. The tape reacts only to the secreted sebum regardless of the water content.

Skin-Thermo-Meter ST 500 is used to measure the temperature of the skin surface, which is the indication of the microcirculation of the skin. The test is based on relative infrared temperature measurement; the device resolution is 0.1 °C, the measurement variability: ± 0.2 °C, the measuring surface covers 2.4 cm. The heads are applied to the surface to be tested, where the device measures the temperature of only the surface of the skin.

The Cerneometer CM 825 was used to assess the level of hydration of the skin surface The test is based on the measurement of the capacitance of the dielectric medium. This device measures the change in the dielectric constant due to the hydration of the skin surface, changing the capacity of the precision condenser. The measurement depth is 10–20 μm to avoid the influence of deeper layers of the skin, e.g. from blood vessels on the test result. The probe head provides constant pressure upon the skin by performing accurate and repeatable measurements.

All the above-mentioned probes were connected to the basic device - MPA Systems - Multi-Probe Adapter. The MPA system works with the general software Courage + Khazaka (Courage and Khazaka Electronic GmbH, Cologne, Germany).

2.2. Research methodology

The skin parameters were tested by means of specialist probes immediately before and after leaving the chamber. The entire test procedure was conducted on the first day (tests I and II) and the tenth treatment day (tests III and IV). The measurements with probes were conducted at the constant ambient temperature of 22 °C and the constant air humidity of 32 g/m3. Before the measurement, the skin had to be thoroughly cleaned at the locations of the application of the probes in order to eliminate the influence of other factors upon the test results.

Probe measuring locations:

- Forehead - between the eyebrows in the area of the so-called "Lion's wrinkle" (location 1),
- The contour of the chin (location 2),
- Cheek - ½ length between the nasal wing and the outer ear section (left - located 3, right - location 4),
- Upper limb - ½ of the length between the wrist and the elbow joint (left - location 5, right - location 6),
- Lower limb - 10 cm above the upper edge of the patella in a standing position (left - location 7, right - location 8).

3. Statistical analysis

In order to compare the data collected during the study, the Wilcoxon signed rank test and the Kruskal-Wallis Test were used. The detailed analysis of the data obtained in the measurement of skin parameters allowed noting statistically significant differences, with a probability $p < 0.05$. Statistical analysis was carried out with IBM SPSS Statistics 20 (IBM Corp, Armonk, NY, USA).

4. Results

The average age of the tested women was 58.7 ± 7.54 years; the average body weight 77.8 ± 16.01 kg, the mean BMI 30.14 ± 5.81, and the average body height 160.7 ± 6.48 cm. Detailed characteristics of measured skin parameters are presented in Tables 1–4.

The greatest variation in hydration was observed between measurements was demonstrated around the left and right cheek. Results of the comparison between skin locations are shown in Table 5.

Subsequent analyses of differentiation did not show statistically significant changes in the pH value of the skin (Table 6) between the successive tests. Only on the first and tenth day of therapy before entering the procedure, one can notice statistically significant differences in the vicinity of “the lion's wrinkle".

The analysis of differentiation also showed no statistically

Table 1
Characteristics of skin hydration [%].

Location tested	Test I			Test II			Test III			Test IV		
	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max
Location 1	58.90	11.90	99.50	52.30	15.40	87.80	45.80	15.80	88.80	46.70	21.50	117.50
Location 2	66.20	48.70	100.70	70.10	29.30	85.40	66.15	48.20	91.20	63.80	47.80	111.40
Location 3	58.05	27.10	97.90	53.95	25.30	91.00	48.85	22.10	82.50	45.15	23.20	98.40
Location 4	54.15	12.90	76.40	59.60	35.10	79.30	59.40	18.13	100.30	51.10	14.80	76.40
Location 5	50.45	30.20	64.90	49.85	31.60	64.10	56.85	37.50	77.50	52.85	31.20	71.80
Location 6	47.80	29.70	71.80	47.10	21.80	68.80	51.55	27.20	74.20	46.25	29.00	71.20
Location 7	39.45	20.20	55.90	38.05	21.30	51.80	40.40	22.90	55.90	36.50	16.60	51.90
Location 8	42.40	17.20	59.80	42.75	21.50	50.80	45.25	26.30	62.00	38.80	20.80	54.70

significant changes in skin sebum value in subsequent tests (Table 7). Only between the first and tenth treatment days after leaving the cryotherapy, significant differences were observed around the right cheek.

As expected, skin temperature underwent significant changes under the influence of extremely low temperature in the cryo-chamber. Most of the analysed differences showed statistical significance (Table 8). This applied mainly to the areas of the upper and lower extremities tested, whereas in the face the temperature did not change significantly in the vicinity of the “lion's wrinkle".

Subsequent analysis concerned the differentiation of tested parameters depending on the test location. Using the Kruskal-Wallis test, it was examined whether significant differences can be distinguished in the values of skin parameters between all measurement locations. A detailed analysis showed that virtually all parameters, at every stage of the tests, the results differ significantly statistically. The exception is the skin pH parameter in tests I and II, which does not show significant differences between the test areas (Table 9).

5. Discussion

In our study, pH of the skin was between 5.5 and 6.08 and. This acidity status is beneficial for the skin and corresponds to the status of the healthy skin. The values of skin sebum within the normal as well and corresponded to values for dry skin. Both, hydration and lubrication of the skin, did not change significantly over the study period and in response to cold. Skin temperature dropped significantly in response to whole-body cryotherapy with the greatest decrease observed in the upper and lower extremities. Our results of the baseline values of skin pH and the level of hydration, lubrication and temperature are in line with reports from the literature [2,10], but reports on changes in these parameters in response to cold are rare.

The increase in the life expectancy of the society and the attention paid to the style and quality of life and their appearance promoted in the media has an impact on the growing interest in cosmetology. It is associated with the growing need for treatments and therapies, whose aim is to improve the appearance of the skin, slow down the ageing process and general body care. Aesthetic medicine and cosmetology thanks to more modern equipment and new therapeutic techniques can offer a range of non-invasive treatments that use healing and regenerating stimuli [3].

The analysis of changes in selected skin parameters performed in this work under the influence of extremely low temperatures in the whole-body chamber showed that the greatest impact was noted in the range of skin temperature. It significantly lowered in many areas of the study. The biggest differences were noted in the area of the upper and lower extremities, which is in line with previous reports from the literature [5]. The hydration parameter after a series of treatments also decreased. Larger changes in hydration were observed in the facial area, around the cheek. Regarding the lubrication of the skin, it is worth paying attention to the amount of secreted sebum, which is significantly higher on the facial skin compared to the skin of the lower and upper limbs. There was no evidence that cryotherapy had a big impact on lubrication; recorded changes rarely showed statistical significance. Based on scientific reports confirming the impact of high temperature on the growth of sebum secretion, one could expect an inverse relationship under the influence of low temperature [2]. However, the results of our research do not confirm such changes. Regarding skin pH values, no statistically significant changes were found here. This parameter remained at a constant level of the acidic environment with no reaction to the applied treatment.

After whole-body cryotherapy treatments, where the skin is subjected to temperatures below $-100\,^{\circ}C$, the reaction of the organism to the cold in the thermoregulation range is carried out in two stages, with the phase of ischemia and reperfusion. In the first phase, it comes to the narrowing of the blood vessels; the blood supply to the skin decreases, which leads to the skin whitening in the place of the stimulus. Cold-stimulated, thermo-receptors in the skin stimulate the nervous system to trigger the body's response to reduce the chilling of the body. The limitation of heat loss is inhibited by vasoconstriction, thus leading to the reduction of blood flow through the skin [1].

The results of our own research have shown that the upper limbs and lower limbs respond more significantly to the cold because the greatest differences between the initial temperature and the temperature after the cryotherapy treatments were noted in these areas. Dębiec-Bąk et al. [11] in the conducted research noted a significant lowering of

Table 2
Characteristics of skin pH.

Location tested	Test I			Test II			Test III			Test IV		
	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max
Location 1	5.93	5.31	6.69	5.90	5.07	6.52	6.08	5.20	7.13	6.02	2.26	6.53
Location 2	5.55	4.88	6.29	5.55	4.86	6.31	5.50	5.17	6.21	5.61	4.34	6.10
Location 3	5.73	4.99	6.21	5.75	5.05	6.21	5.69	5.05	6.41	5.75	4.05	6.14
Location 4	5.54	4.79	6.39	5.56	4.99	6.39	5.56	3.05	8.49	5.55	3.95	6.09
Location 5	5.76	4.74	6.26	5.58	4.93	6.42	5.57	3.65	12.43	5.59	5.15	8.31
Location 6	5.71	4.76	8.72	5.65	4.85	6.48	5.51	5.01	10.61	5.53	4.96	6.22
Location 7	5.80	4.83	9.32	5.62	4.92	6.50	5.78	4.99	12.50	5.65	5.00	11.31
Location 8	5.83	5.24	10.85	5.65	5.04	6.31	5.83	5.08	11.41	5.72	5.06	11.31

Table 3
Characteristics of skin lubrication [μg/cm^2].

Location tested	Test I			Test II			Test III			Test IV		
	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max
Location 1	45.40	5.00	99.00	45.00	100.00	3.00	62.00	4.00	114.00	51.50	5.00	98.00
Location 2	18.50	1.00	121.00	25.00	2.00	76.00	24.50	0.00	87.00	18.50	0.00	76.00
Location 3	11.50	1.00	87.00	14.50	1.00	73.00	24.00	2.00	78.00	33.50	3.00	78.00
Location 4	12.00	1.00	79.00	12.50	1.00	68.00	22.50	0.00	78.00	33.00	3.00	78.00
Location 5	2.00	0.00	45.00	2.00	0.00	45.00	3.50	0.00	40.00	3.00	0.00	36.00
Location 6	2.00	0.00	45.00	2.00	0.00	44.00	3.50	0.00	40.00	3.00	0.00	38.00
Location 7	1.50	0.00	46.00	1.50	0.00	45.00	3.50	0.00	41.00	2.50	0.00	36.00
Location 8	1.50	0.00	45.00	2.00	0.00	44.00	3.50	0.00	41.00	2.50	0.00	36.00

Table 4
Characteristics of skin temperature [°C].

Location tested	Test I			Test II			Test III			Test IV		
	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max
Location 1	32.15	28.00	33.20	31.15	28.40	32.90	31.35	28.50	33.00	30.65	27.50	32.30
Location 2	31.05	27.20	33.20	31.00	28.40	32.90	29.85	27.50	32.60	29.40	26.30	32.70
Location 3	30.35	33.20	27.90	29.45	27.20	34.40	29.30	27.60	31.90	28.00	24.40	30.80
Location 4	30.10	28.10	33.50	29.90	26.20	34.30	29.45	27.40	31.80	28.55	23.50	30.50
Location 5	31.45	29.80	32.50	28.45	22.40	32.00	30.85	29.40	33.20	26.35	20.40	29.70
Location 6	31.70	28.90	33.10	28.20	22.80	32.00	31.40	28.60	33.20	27.20	20.70	30.90
Location 7	29.15	26.40	33.10	24.55	21.70	29.80	28.25	26.30	31.00	24.15	18.40	27.50
Location 8	28.55	26.00	33.50	25.25	21.50	29.60	28.45	26.70	31.10	24.35	17.60	26.80

Table 5
Skin hydration; comparison between measurements before and after treatment (I/II and III/IV) as well as between before measurements (I/III) and after measurements (II/IV).

	Test I	Test II	Test III	Test IV	Test I/II p	Test III/IV p	Test I/III p	Test II/IV p
Location 1	58.90	52.30	45.80	46.70	0.658	0.627	0.455	0.538
Location 2	66.20	70.10	66.15	63.80	0.658	0.627	0.502	0.286
Location 3	58.05	53.95	48.85	45.15	**0.035**	0.882	**0.005**	**0.022**
Location 4	54.15	59.60	59.40	51.10	1.000	0.093	0.344	**0.024**
Location 5	50.45	49.85	56.85	52.85	0.059	0.380	0.177	0.214
Location 6	47.80	47.10	51.55	46.25	0.809	**0.003**	0.079	0.940
Location 7	39.45	38.05	40.40	36.50	0.469	0.076	0.492	0.557
Location 8	42.40	42.75	45.25	38.80	0.658	**0.033**	0.550	0.808

Bold denotes statistical significance.

Table 6
Skin pH; comparison between measurements before and after treatment (I/II and III/IV) as well as between before measurements (I/III) and after measurements (II/IV).

	Test I	Test II	Test III	Test IV	Test I/II p	Test III/IV p	Test I/III p	Test II/IV p
Location 1	5.93	5.90	6.08	6.02	0.778	0.955	**0.002**	0.081
Location 2	5.55	5.55	5.50	5.61	0.778	0.955	0.350	0.494
Location 3	5.73	5.75	5.68	5.75	0.984	0.519	0.896	0.777
Location 4	5.54	5.56	5.56	5.55	0.952	0.279	0.777	0.663
Location 5	5.76	5.58	5.57	5.59	0.494	0.737	0.209	0.896
Location 6	5.65	5.80	5.51	5.53	0.349	0.433	0.687	0.295
Location 7	5.62	5.83	5.78	5.65	0.153	0.494	0.643	0.794
Location 8	5.83	5.65	5.83	5.72	0.098	0.747	0.554	0.513

Bold denotes statistical significance.

temperature under the influence of cryotherapy, also in the areas of the lower limbs and upper limbs. It was found that the lowering of body surface temperature is varied, and the largest decrease is recorded in the limbs. Such behaviour of the organism at the moment of the cold action can be explained by means of several dependencies. Due to thermo-regulatory possibilities, the human body can be divided into a warm-blooded part (a thermal core), i.e. the torso, the head and the cold-blooded part (shield), i.e. the upper and lower limbs. At the moment of stimulation of the cold on the body, the temperature of the body center (including the facial skin) is higher than the temperature of the peripheral parts. In the axial part of the body, there are main organs, generating a significant amount of heat, which is distributed through large arteries. However, in the lower limbs, the amount of heat generated is smaller and is distributed through small vessels. It is also important that the parts of the body whose surface is larger than the volume show a significant loss of heat as compared to other parts of the body [7,11]. The study by Cuttell et al. [6] highlighted that body composition and sex may impact changes of skin temperature following

Table 7
Skin sebum; comparison between measurements before and after treatment (I/II and III/IV) as well as between before measurements (I/III) and after measurements (II/IV).

	Test I	Test II	Test III	Test IV	Test I/II p	Test III/IV p	Test I/III p	Test II/IV p
Location 1	45.50	45.00	62.00	51.50	0.723	0.411	0.159	0.260
Location 2	18.50	25.00	24.50	18.50	0.723	0.411	0.711	0.717
Location 3	11.50	14.50	24.00	33.50	0.571	0.711	0.177	0.151
Location 4	12.00	12.50	22.50	33.00	0.227	0.472	0.112	**0.043**
Location 5	2.00	2.00	3.50	3.00	0.905	0.241	0.270	0.939
Location 6	2.00	2.00	3.50	3.00	0.886	0.306	0.230	0.753
Location 7	1.50	1.50	3.50	2.50	0.742	0.113	0.387	0.360
Location 8	1.50	2.00	3.50	2.50	0.606	0.363	0.423	0.547

Bold denotes statistical significance.

Table 8
Skin temperature; comparison between measurements before and after treatment (I/II and III/IV) as well as between before measurements (I/III) and after measurements (II/IV).

	Test I	Test II	Test III	Test IV	Test I/II p	Test III/IV p	Test I/III p	Test II/IV p
Location 1	32.15	31.15	31.35	30.65	0.823	0.270	0.184	0.093
Location 2	31.05	31.00	29.85	29.40	0.823	0.270	**0.020**	**0.006**
Location 3	30.35	29.45	29.30	28.00	0.191	**0.002**	0.074	**0.002**
Location 4	30.10	29.90	29.45	28.55	0.191	**0.003**	**0.025**	**0.001**
Location 5	31.45	28.45	30.85	26.35	**0.000**	**0.000**	**0.045**	**0.007**
Location 6	31.70	28.20	31.40	27.20	**0.000**	**0.000**	0.116	**0.017**
Location 7	29.15	24.55	28.25	24.15	**0.000**	**0.000**	0.127	0.214
Location 8	28.55	25.25	28.45	24.35	**0.000**	**0.000**	0.370	0.117

Bold denotes statistical significance.

Table 9
Differentiation of the tested skin parameters between the measurement locations in the Kruskal-Wallis test.

Parameter	Test	Asymptotic significance
Skill hydration	I	**0.000**
	II	**0.000**
	III	**0.000**
	IV	**0.000**
Skin pH	I	0.064
	II	0.348
	III	**0.000**
	IV	**0.019**
Skin sebum	I	**0.000**
	II	**0.000**
	III	**0.000**
	IV	**0.000**
Skin temperature	I	**0.000**
	II	**0.000**
	III	**0.000**

Bold denotes statistical significance.

whole-body cryotherapy. They reported significantly greater response to low temperature in men than in women.

The values of all the analysed parameters, apart from the pH of the skin, showed a statistically significant differentiation depending on the location of measurement. There was a significantly higher level of skin lubrication in the facial area, compared to the skin of the lower limbs and upper limbs. The level of sebum of the so-called “Lion's wrinkle” area amounted to 51.50 [μg/cm2], while in the area of the upper edge of the patella in the lower extremity 2.50 [μg/cm2]. The production of sebum depends on the density, location and activity of sebaceous glands. In the facial area, and in particular in the T-zone (forehead, nose, chin), the density of the glands is very large and amounts to 900 per square centimetre of the skin. However, in other locations, for example to the lower extremities, this amount is much smaller and amounts to 100 glands per square centimeter of skin [13].

The facial skin is also more hydrated in relation to the skin of the limbs. Citing the results of the tests, the hydration parameter in the area of the so-called “lion's wrinkle” amounted to 47%, while on the upper edge of the patella in 36%. The proper secretion of sebum correlates with a high level of hydration of the stratum corneum [8]. The same dependence of the level of sebum and skin hydration appeared in the study of Kang et al. [14]. The study analysed the effect of the treatment with the application of low temperature on the skin and was compared with the treatment using radio waves, increasing the skin temperature. The tests were conducted on 21 women aged 30–40. The result of the measurement of the hydration level after a series of treatments in the control group was 53%, in the group in which radio waves were used: 57%, and in the group where cryotherapy was used: 58%. The skin sebum measurement in the control group was 27%, in the group with radio waves 35% and in the group after cryotherapy 34%. Analysing the results of each group, it can be stated that the higher the lubrication of the skin, the higher the level of hydration. It was shown that both treatments with radio waves and the cryotherapy treatment had a positive effect on the tested skin parameters. After applying the treatments, a significant increase in sebum was noted and what is associated with this an increase in the skin hydration [14].

In our own studies, no significant changes in skin pH values were found. In the locations of the pH measurements, it remained at a similar level throughout the experiment. It should be stated that the cryotherapy treatment had no effect on the skin pH. A reverse effect, i.e. the increase in the skin pH, was obtained by the authors using microdermabrasion. It is a treatment based on mechanical exfoliation of the epidermis, thanks to the under-pressure produced by the apparatus. After treatment, a significant increase in the skin pH was noted [9]. This is related to exfoliation of the epidermis, which occurs after applying the treatment. The more damage to the skin surface, the higher the pH is necessary, as the acidic environment is necessary to start the building of the protective lipid barrier [16]. Based on this dependence, it can be concluded that after a series of cryotherapy treatments, there was no change in skin pH, because there was no damage or dysfunction of the protective barrier lipid. The highest pH values are observed in the most hydrated places, which is the facial skin [4].

The research proposed in this study should be continued, analysing the effect of low temperatures on the skin. This will ensure the safety of the patients during cryotherapy and the selection of optimal treatment doses (time and temperature). Sebum, the level of skin hydration and proper skin pH are very important factors in the proper functioning of the epidermal barrier. This barrier plays a key protective role both against water loss and against the penetration of pathogens from the external environment. These issues are not fully explained, so the answers to them should be looked for on the grounds of modern research methods.

The study has some limitation. We enrolled a small group of women; therefore, the study results should be translated to the general population with caution. We included women undergoing whole-body cryotherapy for motor dysfunctions which have been shown to have a neutral effect on the skin temperature. The effect of other comorbidities was not studied.

6. Conclusions

The value of skin parameters depended on the area of testing. The analysis showed statistically significant differences, depending on the measurement location, in all parameters, except the skin pH. The facial skin is more lubricated and hydrated than in other parts of the body. After whole-body cryotherapy, skin temperature decreased significantly, whereas the other parameters changed to a small extent. It can be considered that low temperatures used in whole-body conditions are safe for the skin. Upper and lower extremities are more sensitive to cold than other parts of the body and showed the largest differences between and after cryotherapy.

Conflicts of interest

Authors declare no conflict of interest.

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