Analysis of body surface temperatures in people with Down syndrome after general rehabilitation exercise

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Abstract

The ability to maintain thermal homeostasis is one of the key criteria for the proper functioning of the organism in response to physical exercise. The aim of this work was to analyze the variations in basal temperatures, temperatures immediately after exercise, and after 15 min of restitution in selected body areas in people with Down syndrome and in the control group. Thirty-six people of both sexes were examined. Group 1 (the control group) comprised 18 healthy people whose average age was 29.89 years (± 1.41) and whose average BMI was 30.21 (± 0.92). Group 2 consisted of 18 people suffering from Down syndrome, with an average age of 27.44 (± 1.58) and an average BMI of 30.49 (± 1.73). It was determined that body surface temperatures varied in both groups, depending on the tested area. Statistically significantly lower temperature values were detected in people with Down syndrome, in all body areas. After the general rehabilitation exercise, a statistically significant decrease in body surface temperatures was observed in both groups, which was greatest in the torso area of people with Down syndrome. After a period of post-exercise restitution, people in the control group exhibited a greater efficiency of thermoregulatory processes, with mean values exceeding basal temperatures.

Keywords Thermoregulation · Down syndrome · Obesity · Thermography · General rehabilitation

Introduction

Down syndrome (DS) is one of human's most researched chromosome abnormalities. The clinical symptoms of DS are determined by the additional presence of the third copy of chromosome 21 (trisomy), instead of two copies as is the case in healthy humans [1, 2]. Research teams all over the world are looking for the most efficient therapy methods,

which would improve the quality of life of people with DS and enable them to actively participate in social and professional life. Undoubtedly, well-developed motor skills as well as stamina and endurance constitute an important aspect determining the proper functioning of the body. It entails physiotherapeutic efforts that are correlated with motor skills.

Down syndrome accounts for ca. 1% of genetic birth defects. In Poland, the estimated livebirth prevalence of DS is 1:605, in Germany and the Netherlands, it is 1.36:1000, while in the USA is 1:733 [3, 4].

Trisomy 21 causes a number of multi-level changes in the build and functioning of the body, different internal organs defects, significant metabolic disorders, the appearance of characteristic phenotypic traits, severe hypotonia of skeletal muscles, and varying degrees of mental impairment. It has been proven that excessive gene expression increases the risk of cardiovascular diseases, which leads to the impairment of tolerance to physical effort and decreased endurance. Affected individuals are more prone to fatigue and exhibit intolerance of sustained periods of exercise, especially of aerobic exercise [5, 6].

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DS is connected with abnormalities of nine genes responsible for the development, functioning, and structure of the nervous system [3]. Research has indicated the existence of dysfunctions in hormone balance, which triggers irregularities in the body's adaptation functions [6].

Another characteristic feature of people with DS is decreased muscle tension. In human motor development, the appearance of muscle hypotonia is particularly significant for the body posture and disorders of motor functions [7–9].

The broad spectrum of phenotypic variety in people with DS depends on many factors. From the point of view of physiology and the methodology of effort in the physical activeness of affected individuals, it has been observed that physical function is impaired, which results from changes in the functioning and structure of body systems, motor organs, and the central nervous system, which is also responsible for thermal regulation processes.

The optimal temperature maintained by the human body is determined by the efficiency of thermoregulatory mechanisms. The primary center for thermoregulatory processes is located in the preoptic area, in the frontal region of the hypothalamus, and regulates the intensity of heat reduction responses. The heat conservation center, located in the anterior hypothalamus, controls the intensity of responses that reduce the heat loss ratio by strengthening the processes increasing the body temperature. The set point temperature for maintaining thermal homeostasis is determined by the activeness of the hypothalamus [10, 11].

Technological progress has enabled us to remotely measure body surface temperatures in many areas at the same time using thermography. Thermogram imaging of the distribution of temperatures invisible to the human eye is increasingly often used in medical diagnosis. This method makes it possible to analyze the changes in body surface temperatures occurring in thermoregulatory response to a thermal stimulus or effort [12–14].

This study is intended to analyze the changes in body surface temperatures in people with Down syndrome and in healthy people with simple obesity after general rehabilitation exercise. Of importance is also the understanding of correlations between physical effort and the dynamics of body temperature changes in both groups. The research issue and the assessment of thermoregulatory processes efficiency in healthy people after physical effort or thermal stimuli was analyzed by Cholewka et al. [11, 15, 16]. It allowed the researchers to assess thermal homeostasis of the body in response to thermal or effort stimuli. The obtained results will make it possible to plan the therapy of people with trisomy 21 more precisely.

Research questions:

1. What is the distribution of body surface temperatures in both research groups?

2. Does general rehabilitation training affect the temperature distribution in the research subjects?
3. What is the distribution of body surface temperatures in the research subjects after post-exercise restitution?

Materials and methods

Research material

Within the scope of this study, 36 people of both sexes (19 women and 17 men) were examined. The subjects fell into one of two research groups. Group 1 (the control group) comprised 18 healthy people (9 women, 9 men) whose average age was 29.89 years (± 1.41) and whose average BMI was 30.21 (± 0.92). Group 2 consisted of 18 people suffering from Down syndrome (10 women, 8 men), with an average age of 27.44 (± 1.58) and an average BMI of 30.49 (± 1.73).

Both groups underwent identical general rehabilitation training, with 45-min sessions held twice a week for 30 days. Each session took the form of circuit training with training accessories, adapted to the subject's individual abilities. Training intensity was monitored with the Polar Team 2 system and oscillated at 60–70% HRmax.

The study protocol was approved by the Senate Ethics Committee at the Academy of Physical Education in Wrocław.

Fig. 1 View of areas covered by the subsequent thermograms

Fig. 2 Measurement areas in twelve regions of the body

Surface body temperature registration

Surface body temperatures were registered with the use of thermal camera ThermoVision FLIR SYSTEM 335, Researcher (technical specifications—field of view/min. focus distance: $19^\circ \times 14^\circ/0.3$ m; spectral range: $7.5\text{--}13\text{ }\mu\text{m}$; spatial resolution [IFOV] 2.7 mrad; automatic emissivity correction: variable from 0.1 to 1.0) and transmitted to a personal computer with the Thermo CAM Researcher Professional 2.9 software installed. The body

temperatures registration took place in a dedicated laboratory. Examinations were performed three times: directly before the general rehabilitation exercise (Examination I) and five (Examination II) and 15 min after general rehabilitation exercise (Examination III). Measurements of minimal, maximal, and mean temperatures from selected body regions were carried out in standing position. The thermal images were captured both from the front and from the back side of the body, at a distance of 2 m (Figs. 1–4; Table 1). Before capturing raw thermograms, the subjects remained without outerwear (only in underwear) for about 15 min in order to equalize the body temperature. Qualitative and quantitative analysis of thermal images was performed in 12 regions of the body: the trunk, left and right upper limb regions, and left and right lower limb regions (captured from the front and from the back).

For the purpose of statistical analysis, the results of raw thermograms were averaged as follows: the front and the back side. Finally three areas (upper extremities and trunk and lower extremities) were compared.

Thermal imaging performance protocol

Prior to each thermal imaging of the examined subject, the measurement room was prepared to maintain the same measuring conditions such as the room size of 2×3 m (without windows, installation of the floor and wall heating, tiled surfaces or the plumbing system) and the room equipment (the hytherograph, thermometer, insulation mat, LED light, and manual air-conditioning).

The room temperature was kept constant (by cooling or heating the room during the breaks). The values of the temperature up to 23°C and air humidity 45–55% were monitored during the whole examination.

The subjects were informed about the examination and completed the consent and health form. Next, they received

Fig. 3 Thermal imaging whit Examination I the front and the back side of the body, in the trunk and upper limbs region (A1–A8)

Fig. 4 Thermal imaging whit Examination I the front and the back side of the body, in the lower limbs region (A9–A12)

Table 1 Description of measurement points on the thermograms

A1	Shoulder belt front	A5	Shoulder belt back
A2	Trunk front	A6	Trunk back
A3	Right upper limb front	A7	Right upper limb back
A4	Left upper limb front	A8	Left upper limb back
A9	Right lower limb front	A11	Right lower limb back
A10	Left lower limb front	A12	Left lower limb back

disposable examination outfit (slippers, underwear, head-band/cap) which they wore to the end of the examination. Afterward, they were adapted to the examination taking into account the time relative to the endomorph body type (about 15 min before making the thermogram) in standing or sitting position without the backrest. Subsequently, the thermogram was made. Each time the room was occupied by one subject and one examiner.

Fig. 5 Distribution of average temperatures in the lower limbs region, measured before the exercise, after the exercise and after 15-min restitution

Fig. 6 Distribution of average temperatures in the trunk region, measured before the exercise, after the exercise and after 15-min restitution

Fig. 7 Distribution of average temperatures in the upper limbs region, measured before the exercise, after the exercise and after 15-min restitution

Statistical analysis

The statistical analysis was carried out with the use of Statistica PL software v.9 (StatSoft, Tulsa, Oklahoma, USA). The analyzed variables were checked by the

Shapiro–Wilk test, which showed no evidence to reject the hypothesis of normal distribution.

The statistical analysis of the analyzed parameters is presented using the following measures: arithmetic mean, standard deviation, coefficient of variation, and 95%

Fig. 8 Changes in surface body temperature in all studied regions in group female

Fig. 9 Changes in surface body temperature in all studied regions in group male

confidence intervals. In order to assess the differences between the parameters in the group of people with Down syndrome and the control group, an analysis of variance (ANOVA) was applied along with a post hoc comparison

based on the least significant differences (LSD) method. In all the applied statistical methods, values of examinations and coefficients at a level of $p \leq 0.05$ were regarded as statistically significant.

Table 2 Variations of average temperatures in lower limbs regions in the subsequent examinations, between females in the research group and control group

Duncan's test; variable DV_1 (matrix Down syndrome and control gr.) approx. probability for post hoc comparisons. Error: intergroup mean square, repeated measures, matched = 31,249 df

Group	Sex	Examination	{1} 28,640	{2} 27,908	{3} 28,315	{4} 30,208	{5} 29,436	{6} 30,692
DS	F	1		0.0001	0.0399	0.0000	0.0056	0.0000
DS	F	2	0.0001		0.0108	0.0000	0.0000	0.0000
DS	F	3	0.0399	0.0108		0.0000	0.0002	0.0000
Control	F	1	0.0000	0.0000	0.0000		0.0001	0.0028
Control	F	2	0.0056	0.0000	0.0002	0.0001		0.0000
Control	F	3	0.0000	0.0000	0.0000	0.0028	0.0000	

Table 3 Variations of average temperatures in lower limbs regions in the subsequent examinations, between males in the research group and control group

Duncan's test; variable DV_1 (matrix Down syndrome and control gr.) Approx. probability for post hoc comparisons. Error: intergroup mean square, repeated measures, matched = 31,249 df

Group	Sex	Examination	{1} 29,975	{2} 29,266	{3} 29,472	{4} 31,200	{5} 30,783	{6} 31,600
DS	M	1		0.0001	0.0020	0.0001	0.0061	0.0000
DS	M	2	0.0001		0.2145	0.0000	0.0000	0.0000
DS	M	3	0.0020	0.2145		0.0000	0.0001	0.0000
Control	M	1	0.0001	0.0000	0.0000		0.0092	0.0122
Control	M	2	0.0061	0.0000	0.0001	0.0092		0.0001
Control	M	3	0.0000	0.0000	0.0000	0.0122	0.0001	

Results

In order to image the dynamics of changes in surface body temperatures, the mean values of the analyzed parameters are presented for the regions of the trunk, upper limbs, and lower limbs. An analysis of mean body temperatures in all the body regions in both groups showed statistically significant differences. Since they were observed in all comparisons, this material is so extensive that it is not presented here in a numerical or graphic form.

Additional analyses showed that both groups were consistent in terms of the BMI mass–height ratio, which did not differ in a statistically significant way.

An analysis of the results of Examination I (basal) revealed that surface body temperatures in people with DS were lower in all the regions of the body, both for men and women (Figs. 3–9) and exhibited statistically significant differences (Tables 2–7). For women, the temperature of the trunk region was lower by 1.03 °C, of the upper limbs—by 1.48 °C, and of the lower limbs—by 1.57 °C. In males, the respective differences were 1.07 °C (trunk), 1.28 °C (upper limbs), and 1.22 °C (lower limbs) (Figs. 3–9).

The subsequent analyses of the research results obtained 5 min after the training showed a statistically significant decrease in the temperatures of all the body regions in both groups (Tables 2–7). The greatest decrease in surface body temperatures was recorded in the trunk region in women (by 3.0 °C) and in men (by 2.6 °C) with DS. In the control group, the decrease was, respectively, 2.3 and 2.5 °C. The statistical analyses showed a similar decrease in the temperature of upper and lower limbs in both groups (Fig. 5–9).

The analysis of Examination III (15 min after the training), which measured post-exercise restitution, showed the existence of statistically significant differences in comparison with Examination I before the exercise. This tendency was visible in all the body areas of subjects in every subgroup (with the exception of upper limbs in women with DS) (Tables 2–7). In the control group, the temperature recorded during Examination III exceeded the basal value in a statistically significant way, in all the regions of the body (Fig. 5–9). In all the examined body regions of the subjects in the control group, there was a similar increase in temperature, both in men and in women (Fig. 5–9). The dynamics of changes in people with DS

Table 4 Variations of average temperatures in the trunk region in the subsequent examinations, between females in the research group and control group

Duncan's test; variable DV_1 (matrix Down syndrome and control gr.) Approx. probability for post hoc comparisons. Error: intergroup mean square, repeated measures, matched = 60,782 df

Group	Sex	Examination	{1} 31,263	{2} 28,343	{3} 30,400	{4} 32,294	{5} 30,033	{6} 32,694
DS	F	1		0.0000	0.0018	0.0114	0.0026	0.0006
DS	F	2	0.0000		0.0001	0.0000	0.0001	0.0000
DS	F	3	0.0018	0.0001		0.0000	0.3239	0.0000
Control	F	1	0.0114	0.0000	0.0000		0.0000	0.1214
Control	F	2	0.0026	0.0001	0.3239	0.0000		0.0000
Control	F	3	0.0006	0.0000	0.0000	0.1214	0.0000	

Table 5 Variations of average temperatures in the trunk region in the subsequent examinations, between males in the research group and control group

Duncan's test; variable DV_1 (matrix Down syndrome and control gr.) Approx. probability for post hoc comparisons. Error: intergroup mean square, repeated measures, matched = 60,782 df

Group	Sex	Examination	{1} 32,019	{2} 29,372	{3} 31,469	{4} 33,089	{5} 30,561	{6} 33,544
DS	M	1		0.0000	0.0347	0.0087	0.0004	0.0003
DS	M	2	0.0000		0.0000	0.0000	0.0036	0.0000
DS	M	3	0.0347	0.0000		0.0001	0.0219	0.0000
Control	M	1	0.0087	0.0000	0.0001		0.0000	0.0785
Control	M	2	0.0004	0.0036	0.0219	0.0000		0.0000
Control	M	3	0.0003	0.0000	0.0000	0.0785	0.0000	

Table 6 Variations of average temperatures in the upper limbs region in the subsequent examinations, between females in the research group and control group

Duncan's test; variable DV_1 (matrix Down syndrome and control gr.) approx. probability for post hoc comparisons. Error: intergroup mean square, repeated measures, matched = 64,520 df

Group	Sex	Examination	{1} 29,560	{2} 27,778	{3} 29,138	{4} 31,039	{5} 29,453	{6} 31,439
DS	F	1		0.0000	0.1152	0.0006	0.7788	0.0000
DS	F	2	0.0000		0.0001	0.0000	0.0001	0.0000
DS	F	3	0.1152	0.0001		0.0000	0.4100	0.0000
Control	F	1	0.0006	0.0000	0.0000		0.0000	0.1148
Control	F	2	0.7788	0.0001	0.4100	0.0000		0.0000
Control	F	3	0.0000	0.0000	0.0000	0.1148	0.0000	

was different—15 min after the training, the mean temperatures did not reach the basal values. They were significantly lower than during Examination I (Fig. 5–9, Tables 2–7).

Discussion

The temperature analysis of body surface temperatures is a safe and noninvasive method of observing the thermoregulatory response of the human body to a thermal stimulus or following physical exertion [12, 15–17].

Changes in physiological parameters, which have a visible effect on the difference in body temperatures distribution, are dependent on many factors and processes occurring in the body of every person, such as hormone balance, blood flow dynamics, the differentiation of percentage distribution of various types of body tissues, and personal predispositions to maintain a certain body temperature range (normothermy) [11].

The ability to do physical exercise of varying intensity and achieve satisfying results in physiotherapy is the basic and fundamental aspect of a physiotherapist's work with the patient. Physical movement increases the metabolic

Table 7 Variations of average temperatures in the upper limbs region in the subsequent examinations, between males in the research group and control group

Duncan's test; variable DV_1 (matrix Down syndrome and control gr.) approx. probability for post hoc comparisons. Error: intergroup mean square, repeated measures, matched = 64,520 df

Group	Sex	Examination	{1} 30,831	{2} 28,747	{3} 30,300	{4} 32,058	{5} 29,903	{6} 32,467
DS	M	1		0.0000	0.0376	0.0036	0.0231	0.0002
DS	M	2	0.0000		0.0000	0.0000	0.0070	0.0000
DS	M	3	0.0376	0.0000		0.0001	0.3001	0.0000
Control	M	1	0.0036	0.0000	0.0001		0.0000	0.1076
Control	M	2	0.0231	0.0070	0.3001	0.0000		0.0000
Control	M	3	0.0002	0.0000	0.0000	0.1076	0.0000	

rate, which is connected with faster blood circulation and the speed of oxygen transport. This leads to an increase in temperature, which is also affected by muscle work. In this situation, a very important physiological response is the ability to remove heat from the body by excreting sweat and reducing the increase in internal temperature of the body [18].

The observed changes in body surface temperatures provide much information about the efficiency of thermoregulatory processes, which are decisive for post-exertion homeostasis. Efficient thermoregulation is an important factor in the body's adaptation to physical effort [19–21].

The analysis of the thermograms was based on a comparison of the distribution of surface temperatures in different regions of the body. It offers the possibility to morphologically and functionally depict selected body regions. This is possible thanks to the fact that the human body emits a wide spectrum of infrared radiation, and thermography enables us to visualize the emitted signals. Many studies have shown significant differences in body surface temperatures in thermographic examinations, which seems to indicate the existence of factors that are not fully understood at present. One could speculate that they are connected with somatic traits, age, BMI, type of performed physical exercise, and changes in peripheral circulation [22, 23].

Thermographic images of people with DS in the state of thermal homeostasis provide valuable information about the average mean temperatures of their bodies. Potentially, they can complement the results of screening tests in the diagnostics of existing dysfunctions. It is hugely important in planning the physiotherapeutic process because it can prevent overexertion and injuries to the motor organs; indirectly, it can be helpful in analyzing the human body's response and in preventing hyperthermia. The method can be used in planning the physiotherapeutic process based on movement therapy, taking into account the strength of the

motor organ of people with DS and its resistance to training and rehabilitation load.

Disorders of the central nervous system resulting from trisomy 21 are also connected with dysfunctions of the body thermostat—the frontal and tuberal hypothalamus. Due to the impairment of thermoregulatory processes in people with DS, it seems justifiable to analyze how they respond to changes in temperature resulting from the influence of the external environment and physical exercise.

Thermoregulatory disorders and their effects in people with DS, i.e., intolerance of changes in the external environment and the impairment of the body's ability to adapt to increased training load, have been the subject of many researches [24, 25]. Cocchi studied 432 people with trisomy 21 and focused on their reception of thermal stimuli. The analysis focused on the subjects' individual responses to heat and cold stimuli, their reactions to changes in the temperature of the environment, and observations made by caregivers, e.g., whether the subjects removed sheeting at night, whether they preferred to stay in the sun or in the shade, whether they sweated irrespective of physical effort. The obtained results made it possible to establish that 67.36% of the subjects showed low tolerance of heat, 5.78% were more sensitive to cold, 2.08% were sensitive to both heat and cold, and 19.61% were indifferent to the changes in temperatures. In 4.1% of the cases, it was impossible to obtain credible points of reference. There were also differences depending on the subjects' sex.

Cocchi concluded that people with DS are clearly intolerant of heat, which can be connected with the improper functioning of the thermoregulatory mechanism in the hypothalamus. This conclusion had been supported by his earlier research on people with trisomy 21. By focusing on the substantial deficiency of γ -aminobutyric acid (GABA) in people with DS it was proven that this substance influences the thermoregulation center in the hypothalamus. The results indicated that people with DS, who have low levels of GABA in their bodies, exhibit low

tolerance of exogenous and endogenous heat load [24]. Davidenkova [25] identified the reason for errors in the thermoregulatory mechanism in damage to the red nucleus and showed a direct correlation between improper muscle tension and the ability of people with DS to adapt to the changing temperatures. She also listed significant changes in the anatomical structure, such as the atrophy of the frontal sinuses in people with DS, which leads to the impairment of the possibility of actively regulating the body temperature by using ventilation near the brain. Another important aspect of impaired thermoregulation in trisomy 21 is the lack of the correct systolic blood pressure reaction to a thermal stimulus, which can also influence the use of physical exercise in people with Down syndrome [25].

Taking into account the improper functioning of the thermoregulatory center in people with DS, this research focused on the analysis of the dynamics of body surface temperature changes and the efficiency of the body's thermoregulatory response to physical exercise in general rehabilitation. The findings could be useful in planning the optimal physiotherapy load or using alternative thermal physical stimuli as a component of treatment.

In this research, thermographic registration of the subjects' body temperatures necessary to create an initial thermal map led to the observation of a variation in the analyzed parameter. The temperature analysis accounted for a correlation with the subjects' sex and the BMI of both sexes. In order to eliminate the influence of the body composition on the variation in body temperatures, there were no significant differences in BMI. According to the WHO classification, people with $\text{BMI} \geq 25.0$, which signifies overweight or obesity, may exhibit changes in the distribution of body temperatures [26]. Fatty tissue serves the role of an insulator against both exogenous (external) and endogenous (internal) temperatures, which results from metabolic processes occurring in the human body. Similar distributions of average temperatures in the human body have been recorded by other researchers. In their analysis of average body temperature distribution, Skrzek observed the highest temperatures in the region of the shoulder belt, chest, and the abdominal cavity [27]. Chudecka [28] in their research showed that the temperature of individual regions of the body varies.

In this research, the highest temperatures in both groups were observed in the trunk, upper limbs, and then lower limbs. However, subjects with DS had lower average values in all the analyzed body regions. Supposedly, such significant variations in body temperatures in both groups could result from impairments of the functioning of the hypothalamus in people with trisomy 21.

By analyzing the variations in the distribution of average body temperatures in people with DS and breaking the

results down with respect to sex, a clear difference was observed between women and men. Women with DS had lower average temperatures in the analyzed body regions than men.

However, a statistical analysis of the findings did not indicate a correlation between the variations in both groups' body temperatures and their BMI. Because both research groups showed similar levels of simple obesity as measured by BMI, it enabled the authors to draw the conclusion on the basis of literature on the subject that the linear gradient of both groups with respect to each other may result from the impairment of hypothalamus functioning in subjects with trisomy 21.

The thermal imaging of subjects after general rehabilitation exercise showed a significant decrease in the temperatures of all body regions in both groups. The greatest decrease in surface temperatures was observed in the trunk region of women and men with Down syndrome. At the same time, the decline of temperatures in the lower limbs region in women and the upper limbs region in men was similar in the research group and the control group. Any form of physical activity results in increased tissue metabolism accelerating the transport of oxygen due to faster blood circulation, which in turn increases the body temperature as a consequence of producing heat by the working muscles [29, 30]. If the body is subject to physical or sports exercise, it is important to improve the ability of removing excess heat from the organism (limiting the increase of endogenous temperature and accelerating the excretion of sweat), which makes it possible to continue the effort [30, 31]. The efficiency of the thermoregulatory mechanism is therefore an important element of the body's adaptation to physical exertion. Changes in body surface temperatures in the wake of movement therapy, for example, reflect the speed of removing endogenous heat produced during the effort as well as the body's thermoregulatory response aimed at maintaining its thermal balance.

The general rehabilitation training used in this research project resulted in a significant change in body temperatures both in the group of people with DS and in the control group. The distribution of temperatures confirmed earlier research findings which demonstrate that skin covering areas of the body with rich vascular network displays greater heat than skin directly covering bone areas [32]. Such distribution of temperatures could be explained both by the shape of the analyzed surface and by its thermal inertia. Moreover, the internal organs situated in the trunk and the abdominal cavity, whose functioning results in the production of heat, contribute to maintaining a constant increased temperature in these body regions [27]. The analysis of temperature distribution in the research group could indicate a correct functioning of the hypothalamus.

However, it seems necessary to control the decrease of temperature accompanying physical activity because people with trisomy 21 exhibit greater sweating near the face and neck and an impairment of this ability in response to increased temperature in other body areas. Cocchi's research highlights the number of sweat glands in people with DS in comparison with healthy individuals. In countries with higher average air temperatures, such as Italy or the Sudan, the survival rate for people with DS is lower. The reason for it is the fact that as temperature increases, so does the body's demand for oxygen. This triggers thermoregulatory processes based on faster heart rate, among others, and since ca. 40% of people with trisomy 21 suffer from innate cardiovascular diseases, the excessive burden on the cardiovascular system leads to cardiopulmonary episodes that often cause the patient's death. Numerous genetically conditioned changes in the bodies of people with DS probably influence not only their mental retardation, but also the impaired ability of functioning and adapting to the thermal changeability of the environment [24].

The effects of the subjects' thermal response are also visible in the process of restitution after general rehabilitation effort. Literature on the subject provides many examples of short-term increase of temperature on the basal values during restitution. It results from higher warmth of skin caused by faster blood flows in the analyzed body regions [33].

In this research after 15-min restitution following general rehabilitation exercise, temperatures returned to the basal values, or slightly exceeded them, in all the body regions of the subjects in the control group. The return was very dynamic, which may indicate a quicker response of the body to a thermal stimulus and may influence the efficiency of the body's thermal regeneration [34–36].

The analysis of findings concerning post-effort restitution in both groups revealed a greater increase in average temperatures of all the body regions in the control group. The biggest increase of temperature was observed in the trunk region in both women and men, followed by upper limbs and lower limbs. The same order was observed in subjects with DS, although the increase was less dynamic. However, the values of the analyzed parameters did not reach the basal values, which may indicate an impairment of thermoregulatory processes. Based on the findings of other researchers, it is possible to explain the reasons for the changes in temperatures during the restitution process. The short-term increase in body temperatures on the basal values as shown by the body's thermal imaging map before the training may result from the warming up of the skin caused by faster blood flow after training [30].

Thus, in the therapy and rehabilitation of people with DS, it is necessary to focus on the global character of the applied effort as well as stimulation with physical stimuli,

taking into account the impaired functioning of the thermoregulatory mechanisms.

Conclusions

1. The surface body temperatures showed significant differentiation depending on the analyzed regions of the body in both groups.
2. In both groups, a statistically significant decrease in surface body temperatures after general rehabilitation exercise was observed in all the regions of the body; it was highest in the trunk region in people with Down syndrome.
3. In the group of healthy subjects, after 15-min restitution the body temperatures returned to the basal values and even increased them significantly, whereas in the group of people with Down syndrome, the body temperatures did not return to the basal values. It could indicate a greater efficiency of thermoregulatory processes in the control group.

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