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COMPARATIVE ANALYSIS OF THERMAL IMAGING PICTURES OF NORTHERNERS IN THE AGE ASPECT

Four hundred and fifty-two male residents of Magadan Region were examined to study ontogenetic features in their thermal imaging pictures. Based on the subjective age which ranged 15-74, four groups were formed: adolescents, young men, mature men, and elderly men. The indicators of thermography, hemodynamics, gas exchange and energy metabolism were analyzed We could see the temperatures in both individual zones of the body and weighted averages through all analyzed spots drop in increasing reliance on age. The daily energy consumption at rest, oxygen consumption per kg of the body weight, as well as the oxygen utilization factor were also maximal in the group of young men and minimal in older men. The average group indices of peripheral vascular resistance increasingly varied from adolescents to the elderly, while the cardiac output values dropped in more than half within the same age range.

Keywords: thermography, metabolism, hemodynamics, North, men, adaptation.

Introduction. Human body temperature is known to be a key indicator of vital activity [12]. Metabolism is crucial in endothermic animals as it maintains the basic body temperature within a few tenths of a degree Celsius which is the temperature homeostasis regardless of meteorological conditions but at very high energy costs [22]. Body temperature measurement is one of the oldest quantitative assessments of metabolic balance [25]. In fact, infrared thermography is a non-contact and non-radiation imaging method aimed at studying the physiological possibilities associated with thermal homeostatic actions of the body expressed through thermoregulation of the skin [15]. Modern thermal imaging is a scientifically based method which is widely used in science, technology, and national economy for registering the distribution of the body surface temperature with the possibility of converting the obtained two-dimensional thermal images into a digital form suitable for qualitative and quantitative analysis [27]. The method enables to convert infrared thermal radiation into electric signal which is amplified and then reproduced on the LCD screen as a color picture of the temperature distribution [23]. The homoeothermic body is described by the core-shell model [16]. When it comes to temperature, the core of the body is relatively stable, but the shell of the body (surface tissues and skin mainly) contributes to the regulatory process [24]. It is hypothesized that the skin, as the physical boundary of this model, is a kind of mirror reflecting internal thermodynamic processes.

A person’s age is important in the balance between the body heat production and heat loss. The body’s ability to maintain internal temperature comes down with increasing age [12].

Following on from the above, this study used infrared thermography in order to identify age-associated changes in Northern men based on thermal imaging pictures taken from different zones of the body.

Materials and Methods. Four hundred and fifty-two Caucasian males, all permanent residents of Magadan Region, were examined. The subjects were divided into four groups: adolescents, n=95 (average age 16.2±0.4 yrs, body length 179.1±0.5 cm, body mass 70.5±0.5 kg, body mass index 20.7± 0.4 kg/m^2), young men, n=192 (19.2±0.5 yrs, 178.9±0.7 cm, 66.4±1.2 kg, 21.7±0.2 kg/m^2), mature men, n=109 (38.2±0.7 yrs, 180.1±0.5 cm, 84.1±0.9 kg, 25.9±0.4 kg/m^2), elderly men, n=56 (67.2±1.1 yrs, 172.9± 0.8 cm, 83.9±1.3 kg, 27.9±0.3 kg/m^2).

The thermographic survey was performed in the initial standing position, using a thermal imager of FLIR SC620 (Sweden). The device provided long-wave (7.5-13 microns) visualization with a sensitivity of at least 0.1 °C and a spatial resolution of 640 x 480 pixels. The research was carried out in compliance with the European Thermographic Association standards [11]. We analyzed the pictures obtained with the thermal imager from eight zones, the anterior and posterior parts of the body (Fig. 1): C_1 – the average temperature of the left subclavian area (°C), C_2 – the right subclavian area (°C), C_3 – forehead (°C), C_4 – chest (°C), C_5 – abdominal area (°C), C_6 – upper back (°C), C_7 – shoulder blades / interscapular area (°C), C_8 – lower back / lumbar (°C). For each selected area, the average surface temperature was calculated, which was more representative for that area than its minimum and maximum values. The advantage of infrared systems in comparison with other methods of temperature measurement is that it allows for the simultaneous analysis of a large number of image elements (pixels) in a short period of time, after which real-time processing is possible [14].

We used a Spirolan-M metabolograph (Russia) to explore the level of energy metabolism. The energy consumption at rest, per day (kcal/day), the percentage ratio of energy consumption to the proper level (%), oxygen consumption rate, QO_2 (mL/kg), and oxygen utilization factor, O_2UF (mL/L) were determined.

Cardiovascular system characteristics were studied using a Nissei DS-1862 tonometer (Japan). Cardiac output (CO, mL/min) and total peripheral vascular resistance (TPVR, dyn^2 s cm^{-5}) were calculated.

The investigations were made according to the principles of the Helsinki Declaration; the research protocol was approved by the local Bioethics Committee SRCenter “Arktika” FEB RAS. Male volunteers of different ages were permanent residents of the North, all having similar living conditions and motor activity regimes. Special attention was given to a detailed explanation of the upcoming studies and the participant’s informed written consent was obtained.

The results of the studies were processed using the Statistica 7.0 software package. The distribution of measured variables was tested for normality using the Shapiro-Wilk test; all quantita-

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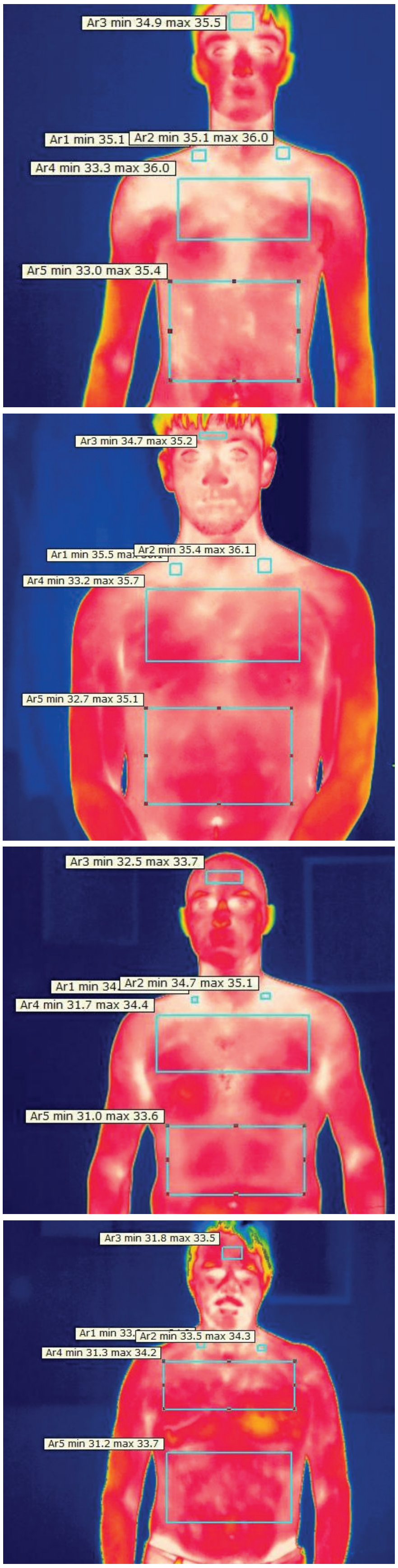
tive data were normally distributed. The processing results are presented as the mean value (M) and its error (±m). The statistical significance of the differences was determined using the Scheffe criterion. The critical significance level (p) in the work was assumed to be 0.05; 0.01; 0.001.

Results and Discussion. The Table shows thermal imaging picture characteristics of the examined male subjects at different ages. The variables of the weighted average temperatures and mean values, as well as all the located surveys (with the exception of C_5 zone – the abdominal surface), the maximum temperatures were seen in the young men (34.91 °C), and the minimum values in the elderly men (33.69 °C). The cumulative temperature drop, thus, amounted to 1.22 °C. The differences (the shift) between temperature extremes grow starting from the upper areas of the ventral part of the body and, conversely, come down in the vertical direction of the dorsal side of the body. So, if we compare the values throughout the groups of young men and the elderly, the temperature difference from the left subclavian area to abdominal area increases from 1% to 5%, while from the upper back to the lower back the dynamics declines (from 6% to 3%).

The highest temperatures among all body areas were recorded in subclavian areas. This was characteristic of all the surveyed groups, regardless of the subjective age. We found the asymmetry values for the left and right subclavian areas: for the mature men the shift was only 0.01 °C, for adolescents 0.03 °C, while for the elderly and young men it was 0.07 °C and 0.09 °C, respectively. The minimum values were seen in the lumbar area, and this was observed throughout the three age-specified groups – from adolescents to men of mature age. The exception was made by the elderly people since their minimum temperatures were found in the abdominal area.

The number of indistinguishable intergroup temperature values of different parts of the body was recorded when comparing: adolescents vs. young men (3 areas), adolescents vs. mature men (2 areas), and young men vs. mature men (1 area). For the rest comparisons, differences were found in all the tested areas of the skin surface. At the same time, when we studied the dynamics for each of the surveyed areas, for which linear (without exception for any group) inter-age differences were observed, the forehead area stood for the front of the body (a decrease in temperature by 0.78 °C (or 2%)) from adolescents to the elderly men), and the back temperature dynamics could be seen in the area under the neck (a decrease of 1.65 °C (5%)) and in the interscapular area of the back (1.48 °C (4%)).



Subjective thermal imaging pictures representing different surveyed groups: adolescent (1), young adult (2), mature man (3), old man (4).

By subjective cardiovascular analysis, we could see the average values of the cardiac output (CO, L/min) feature as follows: 5281.5 ± 90.5 ml for the adolescents, 5699.4 ± 67.2 ml for the early adults, 3715.9± 41.4 ml for the mature men, and 2636.5± 68.5 ml for the elderly men. Such a pronounced lessening in the average CO variables observed with the increasing age obviously occurred together with a growth in the average indices of total peripheral vascular resistance (TPVR, dyn^2 s cm^{-5}) exhibited throughout the groups: 1406.5±28.5, 1468.8± 22.3, 2341.1±31.8, and 3519.7±78.2 for the group of adolescents, early adults, mature men, and the elderly, respectively.

We explored the metabolic picture within the groups and obtained the following average numerical values. The oxygen consumption rate, QO_2 (mL/kg) was equal to 4.23±0.11, 4.28±0.06, 3.58±0.1, and 3.28±0.12 for the group of adolescents, early adults, mature men, and the elderly, respectively. The percentage of energy consumption to the proper level (%) was registered as 1905±60.2 kcal per day (108±2.85% of the norm), 2202±33.3 kcal (121±1.74%), 2067±52.3 kcal (112±3%), and 1787±59.9 (116±3.85%) for the group of adolescents, early adults, mature men, and the elderly, respectively. Finally, the oxygen utilization factor, O_2UF (mL/L) was 23.93±0.43, 36.2±0.2, 29.93±0.77, and 26.03±0.66 for the group of adolescents, early adults, mature men, and the elderly, respectively.

The temperatures of the examined skin areas, as well as their weighted average temperatures were also age-associated becoming lower with the increasing age, from the early adulthood to the extreme old age. Figure shows cases of thermograms by the subjects at different ages.

Our obtained data are comparable with the results of a study [20] which performed an experiment on time computer modeling of the temperature picture that featured the skin on the palm, foot, forearm and lower leg: the authors reported that an older person demonstrated lower temperatures than an average person at a younger age owing to slower basic metabolic rates, cardiac output per min, as well as body mass and body surface area which are characteristic of older ages.

Some authors reported in their recent survey [12] that the elderly (over ≥60

Characteristics of a thermal imaging portrait of males of different ages

	Adolescents (1)	Young men (2)	Mature men (3)	Elderly men (4)	1-2	2-3	3-4	1-3	2-4	1-4
C_1	35.37±0.07	35.59±0.09	35.29±0.05	35.10±0.08	p<0.05	p<0.01	p<0.05	p=0.35	p<0.001	p<0.01
C_2	35.34±0.07	35.68±0.12	35.30±0.05	35.03±0.07	p<0.05	p<0.01	p<0.01	p=0.63	p<0.001	p<0.01
C_3	34.77±0.08	35.14±0.13	34.44±0.07	33.99±0.11	p<0.05	p<0.001	p<0.001	p<0.01	p<0.001	p<0.001
C_4	34.52±0.08	34.61±0.14	34.11±0.08	33.57±0.12	p=0.57	p<0.01	p<0.001	p<0.001	p<0.001	p<0.001
C_5	34.26±0.09	33.95±0.23	33.60±0.10	32.67±0.15	p=0.20	p=0.18	p<0.001	p<0.001	p<0.001	p<0.001
C_6	35.00±0.08	35.39±0.11	34.26±0.09	33.35±0.16	p<0.01	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
C_7	34.52±0.08	35.03±0.12	33.87±0.10	33.04±0.17	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
C_8	33.81±0.11	33.89±0.18	33.48±0.11	32.74±0.17	p=0.70	p<0.05	p<0.001	p<0.05	p<0.001	p<0.001
Avrg temp.	34.70±0.07	34.91±0.11	34.29±0.09	33.69±0.12	p=0.11	p<0.001	p<0.001	p<0.05	p<0.001	p<0.001

Note. Average temperature, °C: C_1 – average temperature of the left subclavian region. C_2 average temperature of the right subclavian region. C_3 – average forehead temperature. C_4 – average breast temperature. C_5 – average abdominal temperature. C_6 – average upper back temperature. C_7 – average temperature in the area of the shoulder blades. C_8 – average lower back temperature

years old) exhibited, on average, 0.23 °C lower temperatures than young people (under <60 years old). In our study, the elderly subjects' upper body surface temperatures in weighted average units decreased by 0.6 °C as compared to mature men, by 1.22 °C compared to early adults, and by 1.01 °C in comparison with the examined adolescents.

In other research [9], significantly higher temperatures were read in the chest, forehead, upper back, and subclavian areas, which is associated with the temperature of internal organs that emit heat as a result of their normal metabolic processes, as well as with a low thickness of subcutaneous fat. As opposed to the above average variables, we received slightly higher forehead temperatures when measuring with an infrared thermometer: subjects under the age of 21 reported 34.43 °C, 41-50-year old subjects – 34.0 °C, and those aged 61-70 had 32.6 °C temperature [7]. Similarly, the Moscow research showed lower values of the weighted average temperatures in the back area (32.3±1.0 °C in adolescents, p<0.001, 31.7±0.12°C in mature men, p<0.001) and chest temperatures (32.2±2.1°C in adolescents, p<0.001) as compared to our results [2]. Our earlier studies also indicated significantly higher average skin surface temperatures as opposed to those in young men living in more favourable climatic and geographical conditions (Moscow, Shchepin (Poland) [4].

Symmetrical hyperthermia of the supraclavicular regions is normally characteristic of the optimum thermal imaging picture of the anterior surface of the chest [26]. The author reported 0.25 °C as maximum temperature of the symmetry [26]. In our study, the temperature difference between the left and right supraclavicular areas in all the examined groups was comparable to that shift (0.025 °C), but there was an increase in thermal asymmetry in the group of elderly men and young men up to 0.07 °C and 0.09 °C. A detailed analysis for better understanding of these processes requires further research.

Physiological thermoregulation encompasses all the mechanisms and processes used by the human body to keep warm. Obviously, physiological changes that develop in the human body with age can also involve a decrease in temperatures from adolescents to the elderly owing in particular to the total body fat growth with increasing age. It has been shown that the percentage of the body fat is the proportion of fat in body mass with low thermal conductivity (38% compared to muscles) and it helps to prevent heat loss. The reason is that a higher proportion of the body fat increases a person's ability to keep heat, which leads to lessening in the average skin temperature [18] since the thermal insulation property of adipose tissue is considered to be one of the most important factors affecting individual thermal patterns [13]. Our previous studies confirmed significantly higher (25.9 ± 0.5%) total fat amount in the elderly people than that of both the mature men (20.6± 0.3%, p <0.001) and the young adults (10.9± 0.2%, p<0.001) [5].

After E.B. Akimov and co-authors [1], some processes which cause differences in subjective temperature pictures can be classified. The first process implies the influence of local blood flow provided by both the density of skin capillaries (anatomical factor) and the tone of vasoconstrictor smooth muscles (factor of autonomic regulation in the vascular tone). It is also necessary to consider the metabolic activity of tissues and the entire body [1]. It is known that the cardiovascular system provides Blood Pressure maintenance and also contributes to thermoregulation as it distributes and dissipates heat throughout the body [20]. Under thermally neutral conditions, the body heat production and loss are equal, and the skin surface temperature is only controlled by the skin tissue blood flow rate [11]. The subcutaneous areas contain venous plexuses which strongly affect skin temperatures and heat transfer from the skin to the environment [3]. Such changes in skin surface temperatures occur primarily owing to changes in peripheral blood flow with the blood working as a conductor in heat exchange between the core of the body and its shell [21]. The level of blood perfusion and the tonic state of the surface vessels are among the main factors influencing the surface temperature distribution [3]. Some researchers also confirmed that a lower cardiac output and a reduced ability to redistribute blood from the visceral circulation lead to a slowdown in skin blood flow in older people [10].

Indeed, our results are in line with the above results since significantly higher CO indices were recorded in the group of young men, which was fully comparable with skin temperatures both in various areas and its weighted average, while the minimum variables for both CO and temperatures were characteristic of the elderly men. It is also possible that a smaller cardiac output in the elderly may reduce their heat exchange [17]. At the same time, the narrowing of peripheral vessels because of the higher sympathetic activity is a stable physiological reaction that minimizes the heat flow from the core of the body into the environment. This peripheral reaction is of particular importance as it provides the first line of protection by minimizing convective heat loss. Our results also confirmed these conclusions as we indicated ageing as a factor accelerating the total peripheral vascular resistance: the smallest values of TPVR were characteristic of adolescents and young men with a significant growth in mature and elderly subjects. Apparently ageing is also a driving factor for lower average temperatures.

By analysis of subjective gas exchange and metabolic rates, we concluded that men at early adulthood demonstrated highest values of oxygen consumption and metabolic indicators (kcal per day) as opposed to examinees of different ages and to the standard values as well, which could be seen in significantly higher variables on their thermal pictures. As for the elderly men, they tended to be significantly lower in gas exchange, within the normative ranges though, with the lowest average temperatures in different areas of the body and the entire thermal picture.

The cutaneous blood flow is also connected with the autonomic nervous system, which regulates vasoconstriction and vasodilation of capillaries to maintain homeostasis [19]. The skin blood circulation is controlled by the adrenergic sympathetic nervous system. In particular, vasomotor sympathetic nerves in the distal extremities are only contractile nerve endings that operate the body temperature by constricting or dilating blood vessels to reduce or expand their lumen [11]. Our previous results showed the lessening in autonomic functions with the increasing age, which was associated with the lowered activity of the parasympathetic link in autonomic nervous system shifting the sympathetic-vagal balance in order to produce the state of relative sympathetic activity [6]. That can also be a driving factor for the lowered average values of the examined elderly men's thermal pictures. Since a lower skin temperature reduces the thermal gradient between the skin and the environment, and because of the rate of the body heat loss that depends on the magnitude of this gradient, the lower skin temperature effectively reduces the heat loss of the entire body and lessens the drop in the core temperature [8]. Such thermoregulation readjustments can be observed in the elderly men. These are accompanied by sufficient daily energy consumption and its percentage ratio to the proper level, which is within the normative range, with a simultaneous decrease in blood flow rate due to vasoconstriction mechanisms caused by the prevailing sympathetic link of the autonomic nervous system. As for younger adults, higher metabolic and resting oxygen consumption rates at high hemodynamic values allow them for maintaining a higher skin temperature and, apparently, show their metabolic adaptation [28].

Conclusion. Our conducted studies have set the optimum thermoregulation having its completion by the early adulthood as we observe the highest thermal variables shown by young men. With the increasing age, however, the average indices of the thermal imaging pictures prove to decline significantly. The growth in thermal asymmetry in groups of elderly men and young men up to 0.07 ^{o}C and 0.09 ^{o}C, respectively, requires further study and analysis. Interestingly, all the subjects exhibited higher temperatures in the examined body areas as compared to people living in more favorable climatic conditions owing, apparently, to the formation of region-specified characteristics of the Northerners' thermal features.

Thus, we can conclude that isolation adaptation is the type achieved by a decrease in the weighted average temperature with appropriate heat transfer, an elevated total body fat content, a lowered energy and gas exchange, though being within the standard ranges (oxygen consumption rate and oxygen utilization factor), owing to vasoconstriction of the circulatory system caused by activation of the sympathetic link of autonomic nervous system in the elderly men. In this case, age-associated isolation adaptation develops with the skin surface thermoregulation deficit which is aimed at optimizing the internal temperature of the body that is the core.

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THR RELATIONSHIP OF PARAMETERS OF THE PITUITARY-GONADAL AXIS AND DOPAMINE WITH METEOROLOGICAL FACTORS IN HEALTHY MEN LIVING IN THE SUBARCTIC

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Aim: to evaluate the influence of circannual dynamics of meteorological factors of the temperate continental climate on the levels of sex hormones and dopamine as well as antisperm antibodies in men living in subarctic environmental conditions.

Materials and methods. The concentrations of follicle stimulating hormone, luteinizing hormone, prolactin, progesterone, dopamine, cortisol, total and free testosterone, estradiol, sex hormone-binding globulin, dehydroepiandrosterone sulphate, antisperm antibodies were determined in the blood by the enzyme immunoassay on a quarterly basis (December, March, June, September) for one year in 20 healthy men of Arkhangelsk. The relationships between the hormonal data and the climatic data were assessed by using the Spearman correlation coefficient.

Results. Seasonal fluctuations in the levels of estradiol and antisperm antibodies are comparable to changes in the daylight hours, fluctuations in atmospheric pressure, temperature and relative humidity. Seasonal changes in luteinizing hormone levels are associated with the fluctuations in atmospheric air pressure. Daylight affect annual dopamine dynamics, which also correlated with atmospheric pressure and relative air humidity. Total and free testosterone levels in men are relatively constant throughout the year and do not appear to be influenced by the weather factors.

Conclusion. An increase in day length and air temperature is associated with an increase in estradiol and dopamine levels and a decrease in antisperm antibodies values. We believe that the seasonality of estradiol and antisperm antibodies is a daylight effect mediated by changes in the melatonin levels, just as dopamine seasonality is mediated by changes in vitamin D levels.

Keywords: sex hormones; circannual rhythm; dopamine; estradiol.

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Introduction. The change of the seasons of the year causes an adaptive restructuring of the body in the inhabitants of high latitudes. The physiological characteristics of the body allow most healthy people to adapt to the climate of the northern regions of the Russian Federation without noticeable disorders, and only a decrease in adaptive reserves can lead to various pathological conditions. At the same time, large-scale studies covering a number of populations in different climatic zones [5, 11, 16, 23] have shown a relationship between meteorological factors and the dynamics of sex hormones.

Several studies in recent years have received conflicting results in assessing the environmentally dependent rhythmicity of sex hormone secretion in men.