Original Article

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EXPLORING AGE AND GENDER-RELATED THERMAL DYNAMICS OF PAROTID AND SUBMANDIBULAR REGIONS OF HEALTHY INDIVIDUALS USING THERMAL IMAGING TECHNOLOGY

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Infrared thermography is a non-contact and non-invasive diagnostic technique. It can be accessible to a broader population, so it has the prerequisites to become a screening method for tumor detection. However, for it to become a standard triage diagnostic tool, it is necessary, along with the training of personnel to perform imaging and the development of software for rapid analysis of the obtained thermograms. To gain an insight into the characteristics of healthy patients, this research examines the influence of gender and age on the temperature differences of healthy individuals in the parotid and submandibular regions.

Key words: face map, skin temperature, thermal asymmetry, thermal imaging

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TERMOVIZIJSKO ISPITIVANJE ZAVISNOSTI TEMPERATURNIH PROMENA PAROTIDNIH I SUBMANDIBULARNIH REGIJA ZDRAVIH OSOBA U ODNOSU NA GODINE STAROSTI I POL

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Termovizija je beskontaktna i neinvazivna dijagnostička tehnika. Može biti dostupna široj populaciji, pa ima preduslove da postane metod skrininga za otkrivanje tumora. Međutim da bi postala standardno trijažno dijagnostičko sredstvo neophodno je, uz obuku osoblja za izvođenje snimanja i izrada softvera za brzu analizu dobijenih termograma. Kako bismo dobili uvid u karakteristike zdravih pacijenata, u ovom istraživanju je dat uticaj pola i godina starosti na temperaturne razlike zdravih osoba u parotidnoj i submandibularnoj regiji.

Ključne reči: temperaturna mapa lica, temperatura kože, termička asimetrija, termogram

INTRODUCTION

A scientific discipline known as infrared thermography is based on detecting infrared radiation from all objects at a temperature higher than absolute zero. After the detector's energy is processed, a pixel map with temperature values determined by a colour scale can be produced. Temperature variations can be tracked on a two-dimensional picture, and the temperatures of particular locations in an area of interest at a given time may be captured [1].

Thermography has a broad spectrum of applications, extending across industry, energy production, construction, and medicine. In the medical field, it is utilized in various disciplines, including oncology, allergology, dermatology, physiotherapy, sports medicine, and even dentistry.[2].

Thermography provides information on neurophysiological functions, vascular and musculoskeletal system dysfunction, local inflammatory process, localization, and extent of malignant diseases. [3, 4].

The term clinical thermography was first used by Dr. Champan in 1978. He tried to make a distinction between medical thermography only as a diagnostic method, i.e. a method that only detects a functional disorder, and clinical thermography, which, together with clinical findings, explains the diagnosis established by thermography and influences the choice of therapeutic procedures [5]. Clinical thermography is a functional method that, like electrocardiogram, blood pressure measurement and electroencephalogram, relies on information about the function of individual systems and establishes a diagnosis based on that. Unlike functional, structural procedures such as ultrasonography, X-rays, nuclear magnetic resonance, and histological examinations, diagnoses are made by studying the structure of the observed tissues and organs.

Based on recently published research, there has been a visible effort to explore the possibilities of infrared thermography in the early detection of various pathological conditions of the head and neck region [6].

At normal temperatures, human tissues are excellent emitters of infrared rays. According to studies, the majority of infrared radiation generated by the human body has long wavelengths (8-15 m) [6, 7]. Infrared cameras may transform the emitted radiation into electrical impulses, which can be presented as temperature readings using colours. Finally, a quantitative temperature map of the area of interest is created, which may be used to diagnose various disease conditions [7].

The connection between the body temperature and tissue metabolism allows thermal imaging to be used to assess disease processes, injuries, and inflammatory processes. It also allows for follow-up and monitoring of the therapeutic procedures [8].

At present, thermography is being used with growing frequency not only for assessing changes in skin temperature but also for correlating surface temperature patterns with the condition of underlying tissues in the region of interest. These efforts aim to explore the potential of infrared thermography as a diagnostic tool for specific diseases.[9, 10].

The thermal characteristics of healthy people's face must be identified to use a thermal camera to diagnose the condition of specific areas on the face. In this paper, an analysis of the influence of age on temperature changes in the mentioned regions of healthy people will be performed, to establish the feasibility of infrared thermal imaging as a reproducible, non-invasive method for assessing changes in skin temperature within the parotid and submandibular region in vivo.

THE THERMOREGULATION MECHANISM OF A LIVING BODY

The widespread consensus is that an ideal body core temperature is 37.0 with a standard deviation of 1.0°C [2], although publications devoted to this topic indicate values of 36.8°C with a standard deviation of 0.5°C [11, 12]. The body's core temperature is known to be maintained at a constant value in thermodynamic equilibrium, but disruptions like stress, exertion, or illness may cause it to fluctuate [13]. The skin is the most exposed tissue on the body, and as a result, it is highly reactive to variations in the ambient temperature; it is stated that, under normal circumstances, the skin's typical temperature ranges between 32°C to 35°C [11]. A living body must maintain thermal homeostasis to function, which necessitates the generation of thermal energy (thermogenesis) on the one hand and the elimination of excess heat (thermolysis) on the other [14]. Radiation, convection, sweat evaporation, and respiratory and excretory systems are used to lose heat, whereas thermogenesis depends on metabolism, skeletal muscle activity, and gastrointestinal function [15]. The brain's hypothalamus centre, which oversees all functions, regulates temperature changes in the skin and internal organs using a network of thermal receptors. The temperature is stabilized by starting the appropriate thermoregulation processes [14]. As a result, the body no longer experiences either cold or heat. Thermal sensors are then converted to a thermometric state. While the hypothalamus reaches its neutral point at 37°C, skin receptors attain their resting activity at 33°C to 34°C [2]. In other words, the temperature of the body's interior is primarily constant. It has an average of 37°C, although "normal" temperatures can also be considered in the range of 36.1°C to 37.2C, and age, gender, and time of day have a certain influence on it [16]. The average temperature of the skin is subject to the influence of both environmental and internal factors. There is also a difference in the temperature of the skin of certain parts of the body, so it is lower on protruding parts such as the earlobes and cheekbones of the fingers, and it is also lower, for example, above the tendons and bones in relation to regions above the muscles. It is also higher in the areas above the organs with increased metabolic activity [17].

According to statistics from the literature, metabolic activities are considered the body's primary thermal energy source, and about 60% of all energy is used to produce heat [11, 14]. The body needs to be protected from overheating due to the significant thermal energy generation. At rest, energy is typically lost by radiation (54-60%), convection and conductivity (25%), sweat evaporation (7%), and respiration (14%), among other processes [11]. The process of metabolism is essential for maintaining life, but it is highly dependent on the physiology and health of the human body. When compared to a rested body under normal circumstances, factors like illness, pregnancy, or physical exertion have a considerable impact on metabolism levels.

In healthy individuals, there is a symmetrical distribution of skin temperature values in relation to the axis placed in the middle plane of the body. It is an essential factor in determining physiological abnormality with thermography.

For this research, it is most important to note that the development of a disorder in the form of local inflammation also results in a local increase in metabolism [6]. Given that this paper presents research related to the assessment of age-related changes in skin temperature in a control group in specific regions of interest, special attention should be paid to detecting a temperature disorder manifested as temperature asymmetry.

THERMOGRAPHIC INVESTIGATION

Measurements presented in this paper were performed at the Clinic for Dental Medicine Niš, maxillofacial surgery, and at the Faculty of Electronic Engineering Niš, between April 2021 and September 2023. One hundred forty healthy persons, 78 females and 62 males, aged 19 to 87, were examined. (Figure 1).

Thermographic data were acquired using the infrared thermographic camera Varioscan high-resolution model 3021 (Jenoptik, Germany). The camera's sensitivity is 0.03 K. Images were stored on a memory card in the IRB file format and processed using specialised software. The thermograms were analysed in the IRBIS Professional 2.2 application, during which areas of interest were marked, i.e., the parotid region X1, and the submandibular region X2 (Figure 2).

With the first clinical applications of thermography in medicine in the 60s and 70s of the last century, the need for standardization of thermography imaging techniques arose. The European Association for Thermology, then the European Thermographic Association, published two guides that specified the conditions and rules of thermal imaging in medicine [18, 19]. They described the basic techniques for using thermal measurements in clinical practice and clinical studies. Over time, these rules and recommendations were adapted to modern needs following new scientific knowledge and the development of imaging technology. A new protocol was published in 1997. that presented an overview of the previous publications of the relevant associations, namely the American Association for Thermology, the Japanese Society for Biomedical Thermology, and the European Association for Thermology [20].

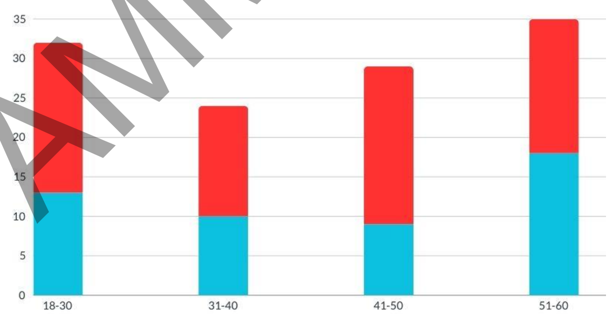

Figure 1. *Age and gender distribution of the study participants (- female, - male)*

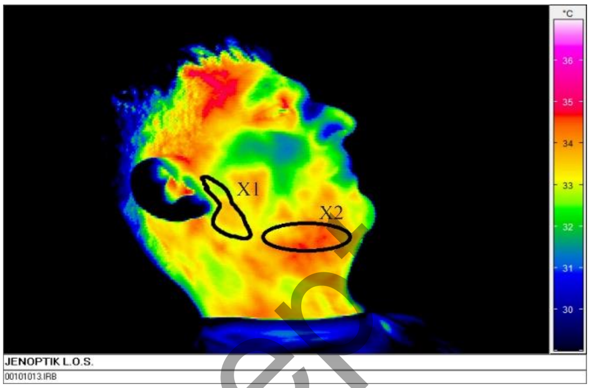

Figure 2. *A thermogram of right side of the face. The parotid region (X1) and submandibular region (X2) are marked*

The effectiveness of clinical thermography depends on the following factors [21]:

- adequate preparation of the patient;
- adequate application of thermal imaging cameras;
- adequate analysis and quality of thermogram storage techniques.

Modern thermographic protocols are based on the guidelines of the American Academy of Thermology [22], as well as on the recommendations of Ring and Ammer [23], and they recommend the following procedures and measures:

- The examining clinician provides a detailed explanation of the dental or systemic health rationale for performing infrared imaging and addresses all patient inquiries or concerns regarding the procedure.

- No clothing or garments should cover the anatomical region under investigation during the examination.
- On the day of imaging, subjects are instructed to take a shower or bath in the morning to ensure optimal skin cleanliness.
- The application of any topical substances, including lotions, deodorants, moisturizers, ointments, makeup, hair products, or topical analgesics, must be strictly avoided to prevent alterations in skin emissivity.
- The use of nicotine should be discontinued at least four hours prior to imaging, and consumption of hot or cold beverages should be avoided for 10–15 minutes before the examination.
- The distance between the subject and the infrared camera should be maintained at approximately one meter. Environmental conditions are standardized, with ambient temperature set at 23–24 °C and relative humidity maintained between 50% and 70%.
- The imaging room should be devoid of direct solar radiation, artificial lighting, and active heat sources to prevent thermal artifacts.
- Prior to image acquisition, subjects should remain seated for an acclimatization period of approximately 15 minutes to achieve thermal equilibrium. During this time, they should refrain from physical activity, chewing, or touching the facial region

The Japanese Society for Thermology gave its recommendations for thermal imaging measurements in dentistry, and these were supplemented by Koriyama et al. [24], and those recommendations imply additional requirements:

- in the room where the measurements are taken, disable the draft and turn off the air conditioners;
- keep a distance between the body that emits infrared radiation and the examined subject;
- when measurements are taken in winter conditions, take a break of at least 20 minutes before starting the recording;
- in the subject's history, enter the following information: first name, last name, gender, age, data on alcohol and cigarette consumption, previous diseases of the subject, current illness, current medical treatments and therapies, and available diagnostic findings.

The camera was calibrated considering the emissivity parameters of the human body (ε=0.98) and the ambient conditions (humidity and temperature). A thermal measuring range was from -40°C to 100°C, a pixel infrared resolution of 86 400 (360×240), and adequate colour palette was selected for optimal colour registration. A standard protocol was used by positioning all the electronic devices at least 2 m from the participant, covering windows and reflective surfaces with adequate covers, and turning off artificial light sources. The room temperature was set to 23±1°C, and the air currents were directed away from the participants and toward the room's periphery. All participants underwent the same thermographic protocol based on the abovementioned requirements, and all thermal measurements were taken in the morning.

A profile-guided thermography scanner setup was designed to provide an equal distance between the camera and the face. This is very important from the angle of adequate control and comparing the thermograms of the left and right sides of the face. This was achieved by having the participants sit on a chair whose axis of rotation symmetry coincides with the axis of the head and neck while the camera was installed on a tripod placed 1 m from a participant.

The data analysis was performed using the Statistical Package for Social Sciences (SPSS) version 23.0 (SPSS Inc., Chicago, IL, USA).

The temperature difference was tested through two types of statistical tests, as follows:

- the right and left side of the face separately for parotid and submandibular region (test T1);
- the right and left sides of the face for parotid and submandibular region separately in men and women (test T2);

The difference in the mean temperature of the corresponding sides of both regions was tested by paired-samples t-test ($T1_1$), one-sample t-test ($T1_2$), and independent samples test (T2).

Additionally, the dependence between mean temperature values and age groups was examined by analysis of variance (ANOVA). ANOVA is a statistical approach for comparing the means of an outcome variable of interest for different groups. For this test, all participants were divided according to age into five groups (with *N* members), namely:

- 18-30 years - age group I (*N*=32);
- 31-40 years – II age group (*N*=24);
- 41-50 years – III age group (*N*=29);
- 51-60 years - age group IV (*N*=35);
- over 61 years - age group V (*N*=20).

A *p*-parameter value lower than or equal to 0.05 was assumed to determine statistically significant differences. In other words, the significance level was assumed to be 95%, and the type II error is 0.2 (for 80% of study power). In this analysis, the comparative model for measurements of both regions, on both sides of the face, is also assumed.

RESULTS AND DISCUSSION

First, the variables related to the left and right sides of the parotid and submandibular regions were tested with the One-Sample Kolmogorov-Smirnov Test to verify the existence of a normal distribution of the data (mean values of the measured temperatures in certain areas). Also, two new variables were introduced that represent the temperature difference between the mean temperature values between the right and left parotid (*dTp*) and submandibular (*dTs*) regions.

One-Sample Kolmogorov-Smirnov Test confirmed that the variables related to the right and left parotid regions and the right submandibular region have a normal distribution (p=0.200). In contrast, the normal distribution was not confirmed for the variable related to the left submandibular region (p=0.002).

On the other hand, based on the sample size (N=140), it can be assumed that the distribution of mean values is normal regardless of how the values are distributed in the population. The previous assumption can be justified using the central limit theorem, i.e., if the sample size increases sufficiently, regardless of the distribution of the basic set, the sampling distribution of arithmetic means tends to a normal distribution [25]. The accuracy of this assumption was verified by testing the newly introduced variables using the same test. The results showed a normal distribution for both variables (p=0.200 for *dTp* and p=0.081 for *dTs*). That means that the differences between pairs of measurements (temperatures of the right and left regions) are normally distributed, so parametric t-tests can also be used for variables related to the submandibular area.

After applying the T1 test, it can be concluded that there is a statistically significant temperature difference between the left and right parotid region of the face (t_{139}=4.394, p<0.001) but that the mean value of the difference is insignificant (approximately 0.1°C), and is in the range from 0.05°C to 0.14°C, that is (95% CI [0.0530, 0.1396]), where CI is confidence interval (Table 1). The test results show that the right parotid region is slightly warmer than the left and that there is a slight difference (approximately 0.1°C) between the right and left parotid regions compared to the difference between both submandibular regions (t_{139}=4.161, p<0.001).

Table 1. *t-test statistics output*

Test no.	Area descriptions	N	Mean (ºC)	SD	t	df	sig.
$T1_1$	Parotid right	140	33.31	0.87	4.394	139	<0.001*
	Parotid left	140	33.21	0.83			
	Submandibular right	140	33.45	0.94	-1.376	139	0.171
	Submandibular left	140	33.48	0.95			
	dTp	140	0.10	0.26	4.161	139	<0.001*
	dTs	140	-0.03	0.26			
$T1_2$	dTp	140	0.10	0.26	8.044	139	<0.001*
	dTs	140	-0.03	0.26	2.259	139	0.025*
T2	Parotid right - men	62	33.15	0.86	-1.891	138	0.061
	Parotid right - women	78	33.43	0.86			
	Parotid left - men	62	33.03	0.83	-2.350	138	0.020*
	Parotid left - women	78	33.36	0.80			
	Submandibular right - men	62	33.67	0.81	2.487	138	0.014*
	Submandibular right - women	78	33.28	1.00			
	Submandibular left - men	62	33.72	0.80	2.737	138	0.007*
	Submandibular left - women	78	33.29	1.01			
	dTp - men	62	0.12	0.27	1.117	138	0.266
	dTp - women	78	0.08	0.25			
	dTs - men	62	-0.05	0.28	-0.890	138	0.375
	dTs - women	78	-0.01	0.24			

**statistically significant difference; df - degrees of freedom; SD - standard deviation*

The difference in mean temperature values in the mentioned regions for men and women was tested with the T2 test. First, the results of Levene's test of equality of variances did not show significance, so it is concluded that there are no differences in the variances of all variables.

The existence of a statistically significant difference in the mean values of temperatures of the submandibular region between men and women was determined between their right sides (t_{138}=2.487, p=0.014) by 0.39ºC and left sides (t_{138}=2.737, p=0.007) by 0.43ºC. The test mentioned above also determined that there is a difference in the temperature values of the left parotid region between men and women by -0.33ºC (t_{138}=-2.350, p=0.020), i.e., that the difference in mean values of the temperature of the left parotid region in women is by 0.33ºC on average higher than in men (Table 1).

As for the right parotid region, no statistically significant difference in temperature values between men and women was confirmed (p=0.061>0.05). Also, in the control group, it was not confirmed that in women and men, there are differences in temperature between the corresponding regions on the right and left side of the face (p=0.266 for *dTp* and p=0.375 for *dTs*), i.e., gender does not influence the differences in temperature of the observed regions between both sides of the face.

CONCLUSION

After analysis of variance, it can be concluded that the mean values of temperatures of the parotid regions are statistically significantly different for at least one of the five age groups ($F_{4,\,135}$=7.239, p=0.001 for the right, and $F_{4,\,135}$=6.021, p<0.001 for the left side of the face).

The Tukey HSD Test was used as a posteriori (post-hoc) test. The test found that there is a statistically significant difference in the average temperature values of the parotid region of the right side of the face between I and IV age groups by 0.88ºC (p<0.001), as well as between I and V age groups by approximately 1ºC (p<0.001).

Also, the test mentioned above determined a significant difference in mean temperature values of the parotid region of the left side of the face between I and IV age groups by 0.78ºC (p=0.001) and between I and V age groups by 0.89ºC (p=0.001).

The previous indicates a decrease in temperature in the observed regions with age, and the ANOVA test was used to calculate the size of the effect (η^2 - eta squared) of age on the decrease in temperature in the parotid regions. Age greatly influences decreasing temperatures of the right (η^2=0.177) and left parotid regions (η^2=0.151). This significant and constant change in body temperature can provide a framework for understanding changes in human health, like a marker for metabolic rate.

In addition, using the $T1_1$ test, strongly positive, almost ideal, correlations were found between the mean temperature values of the right and left side (r=0.954, p<0.001 for the parotid, and r=0.962, p<0.001 for the submandibular region), i.e., the temperature change of one side of the face must be accompanied by a temperature change on the other side of the face (r is Pearson correlation coefficient).

In the continuation of the research, multivariate linear regression will be used for a more precise determination of temperature changes over time, and it is necessary to consider body weight, height and narrower age groups additionally.

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