Craniofacial Temperature Differences between Permanent and Temporary Residents in Arctic Zone Through Infrared Thermographic Analysis

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Abstract

Nowadays, the use of infrared thermography is increasingly being applied as a diagnostic tool. A study explains environmental factors in the Arctic Zone in order to conduct research through infrared thermography approaches to identify temperature differences in craniofacial areas is still limited.

The aim of this article is to determine the difference in craniofacial temperature by applying infrared thermography between permanent and temporary residents in the Arctic Zone.

The volunteers (N = 400) are divided into two distinct groups: 200 permanent residents as a permanent group and 200 temporary residents as a temporary group. The volunteers met the exclusion criteria. The ThermoTracer thermal imager TH9100XX NEC, USA is mounted on a tripod in a vertical position at a distance of 0.71 m in all facial shots: front, right and left views, and the lens is positioned parallel to the appropriate plane to obtain the image. T-test was analyzed with a significant level of $p \leq 0.05$.

The analysis show that 13 out of 29 areas in the craniofacial area between the temporary and permanent groups showed significant differences ($p \leq 0.05$). From these 13 areas it is then found that only two areas in the craniofacial area show significant differences between the permanent and temporary groups. These two areas are: the left temporomandibular joint and the right temporomandibular joint.

It can be difficult to use infrared thermography as a diagnostic tool with the aim of identifying pathological abnormalities in craniofacial area of the Arctic Zone population, particularly temporomandibular joint area.

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Introduction

Indications of thermal imaging uses have been established for decades. Currently, the thermal body pattern is one of the best indicators of human health status. The thermal configuration of the body can determine changes in the human body. Changes in the body's thermal pattern are indicative of a potential pathological process[1]. The examination of the thermal pattern considers advances in general medical strategies. One of the methods which working principle is to determine the characteristics of the thermal pattern is Infrared Thermography.

Since infrared thermography capability has been approved to detect many groups of diseases at once, the use of infrared thermography in humans is more intensive in its application as a diagnostic tool. This technique allows a medical or dental practitioner to determine the localization of intentional changes and be able to spot signs of disease in the preclinical stage. The result data and thermal imaging reliability are close to 100% and for the primary examination is around 80% .[2] In addition,

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as a non-invasive and low-cost technique, infrared thermography causes no discomfort to the patient. Infrared thermography is completely safe and easy to operate. Even for more frequent use, the security level is very safe. This technique is also possible to use for pregnant women and children. [3]

One of the weakness of infrared thermography is that it takes into account several factors that can influence either the analysis or interpretation of thermal image.[4] Factors that can influence analysis and interpretation are known as environmental factors. Temperature as an environmental factor is essential for most applications of infrared thermography in humans.[5] The majority of references recommend a temperature range of 18-25°C, as subjects can shiver at lower temperatures and sweat at higher temperatures.[6]

Cold temperatures, bad weather conditions, and prevailing darkness in winter are among the many challenges of conducting research in the Arctic Zone.[7] The geographic areas of the Arctic Zone which include Canada, Greenland, Denmark, Iceland, Norway, Sweden, Finland, Alaska, and the northern part of Russia are the area with the Arctic climate.[8] The population of the Arctic region is 4 million people, spread over a large geographical area, in an ecosystem that is highly adapted to the harsh and sensitive climate. Many permanent residences living and working with limited access during daylight and cold temperatures.

One of the contributors of the increasing temporary residents' number in the Arctic Zone are international students. Most of the international students who enroll to Russian universities come from tropical countries. In 2016 the number of foreign student enrollments at the Russian Federation was 244,597 students. During 2017, the number of students from tropical countries at Russian universities increased by 17%. The number of students from India increased by 20% and from China by 10%. The country's Ministry of Education also enrolled 3.1 thousand students from Vietnam and 11 thousand students from African countries have been admitted to Russian universities in 2015-2016.[9]

Research that describes environmental factors in the Arctic Zone for conducting research through infrared thermography approaches is still limited. Therefore, it is important for researchers to consider the cold in the Arctic zone as a factor in the application of infrared thermography in measuring the phenomenon of temperature differences in the craniofacial area between permanent and temporary residents. The purpose of this article is to study and determine the differences in temperature of the craniofacial area by applying infrared thermography to permanent and temporary population groups in the Arctic Zone.

Materials and methods

Study design

This study was approved by the Ethics Committee of the Institute of Biomedical Research of the Northern Arctic Federal University and carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. Each *voluntarily* agreed to participate by signing an informed consent statement. The research sample was the craniofacial region of the selected subjects. The sample required in the study is in accordance with the formula used in cross-sectional research for medical research:

$$n = \frac{Z^2 P\,(1-P)}{d^2}$$

$$Z^2 = \text{is normal variate in p} < 0{,}05 = 1{,}96$$

$$\text{P} = \text{expected propostion in population based on previous study}$$

$$d = \text{absolute error or precision} = 5\%$$

According to the analysis of epidemiological data of recent years, the prevalence of diseases of the craniofacial region in specialized dental institutions reaches 56.3%. Therefore, the sample size of this study is:

$$n = \frac{1{,}96^2 \text{X } 0{,}563\ (1-0{,}563)}{0{,}05^2}$$

$$n = \frac{0{,}95}{0{,}0025} = 378$$

Based on this formula, minimum subject for each group is 189 subjects. The subject divided into two groups: the permanent residence group and the temporary residence group. The volunteers met the exclusion criteria: age less than 20 years or no more than 30 years; no orthodontic or physiotherapeutic treatment; medications such as analgesics, anti-inflammatory agents, muscle relaxants or vasoactive agents are not used during the two weeks prior to the measurements; there are no systemic diseases, facial injuries, sleep disorder, TMD, and osteoarthrosis. The female subjects had not undergone in menstrual cycle. Smoking, eating or drinking were not allowed during the two hours before the recording.

Infrared thermography

Volunteers remain in the room 12m^2 for 20 minutes with controlled temperatures. During the survey, relative humidity and room temperature were recorded. During that time, volunteers were instructed not to palpate, not crush, not rub or scratch the skin, not to relax their chewing muscles, and open their lips slightly until the examination is complete. [10] The distance between the volunteer and the camera (ThermoTracer thermal imager TH9100XX NEC, USA) was 0.71 m for all facial shots: front, right and left views. The thermographic camera was mounted on a tripod in a vertical position, and the lens is positioned parallel to the Appreciate plane in all cases to obtain images.[10]

The examination was carried out calmly, without moving the head, the operator moves the machine so that the camera lens: 1) was located parallel to the appropriate plane, 2) was oriented perpendicular to the plane, and 3) towards the lowest possible tilt angle plane. The infrared thermography camera must be turned on at least 10 minutes before measurement to stabilize the camera's electronic components relative to environmental conditions.[11]

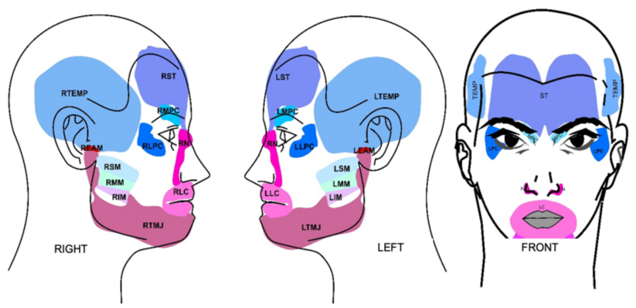

Figure 1. Craniofacial Observation Area modified from Haddat et.al[10]
ST: Supratrochlear; TEMP:Temporal; MPC: Medial Palpebral Commissure; LPC: Lateral Palpebral Commissure; LC; Labial Commisure N: Nasolabial; IL: Inferior Labial; TMJ: Temporomandibular joint; EAM: External Acoustic Meatus; SM: Superior Masseter; MM: Middle Masseter; IM: Inferior Masseter.

Thermogram interpretation and data evaluation

After receiving all the thermographic images and divided into separate files for each volunteer.[12] Identification of craniofacials by adopting areas of interest by Haddad et.al[10] (Figure 1).

Analysis

The results were analyzed using T-test with a significant level of $p \leq 0.05$. The temperature range distribution of each side is described through visual images.

Results

The characteristics of the subjects

Total subject participated in this research is 400 subjects (age range 18-20, mean 19.1). The subject divided into two groups: 200 subjects for the permanent residence group (Female: 103; Male: 97) and 200 subjects for the temporary residence group (Female: 99; Male: 101). The characteristics of the subjects participating in this study is shown in Table 1 below:

		Sex		
		Female	Male	Total
Group	Temporary	99	101	200
	Permanent	103	97	200
Age	18	58	56	114
	19	71	66	137
	20	73	76	149
Total		202	198	400

Table 1. The characteristics of the subjects.

In general, the craniofacial temperature on female group showed a higher temperature than male group. There were sixteen craniofacial areas in female group that differ than that male group with mean difference 0.01-0.21°C (data not shown). However, result shows no significance difference ($p \geq 0{,}05$) craniofacial temperature between female and male.

Right and Left Side

In general, the craniofacial temperature on the left and right of the permanent population group showed a higher temperature than that of the temporary population. The distribution of the mean of temperature differences between the left-right and front sides of the two groups is shown in Figure 2.

There were seven craniofacial areas in the temporary group that differ ($p \leq 0.05$) between the left and the right, namely: Supratrochlear, Medial Palpebral Commissure, Lateral Palpebral

Commissure, nasolabial, labial commissure, TMJ, and Middle Masseter. Meanwhile, for the permanent group are temporal and TMJ areas (Table 2).

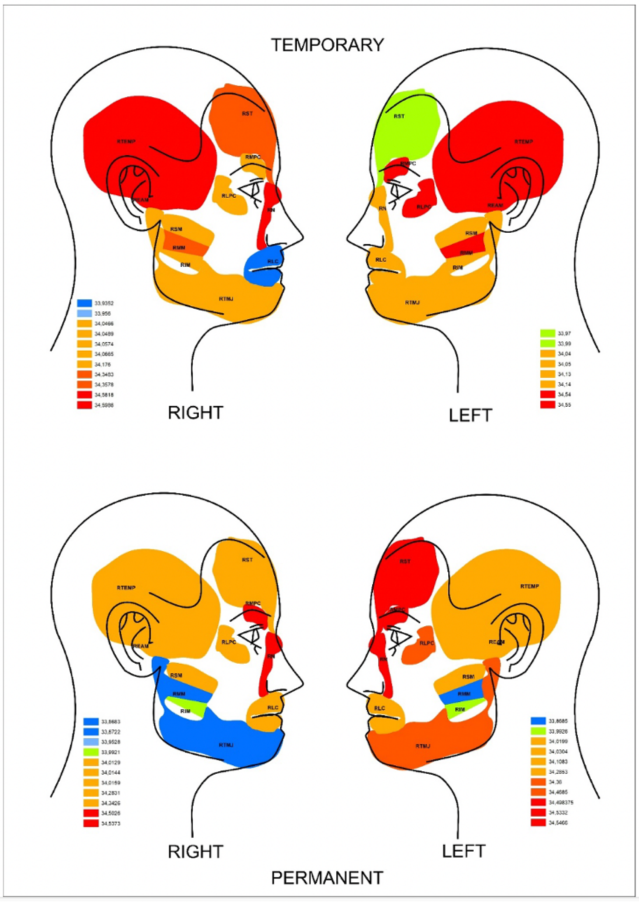

Figure 2. The distribution of the Craniofacial Area Temperature Range in the two groups.

No	LEFT AND RIGHT-CRANIOFACIAL AREA	TEMPORARY Mean	Std. Dev	Sig. (2-tailed)	PERMANENT Mean	Std. Dev	Sig. (2-tailed)
1	Supratrochlear	-0,35	0,86	0,00	0,16	1,22	0,07
2	Temporal	0,00	0,15	0,74	0,27	1,56	0,02
3	Medial Palpebral Commissure	0,51	1,21	0,00	0,00	1,20	0,96
4	Lateral Palpebral Commissure	0,53	1,25	0,00	0,14	1,38	0,16
5	Nasolabial	-0,51	1,20	0,00	0,04	1,22	0,61
6	Labial Commissure	0,16	1,11	0,04	0,02	1,13	0,83
7	TMJ	-0,01	0,04	0,01	0,60	1,20	0,00
8	External Acoustic Meatus	0,00	1,36	0,96	0,16	1,55	0,16
9	Superior Masseter	0,00	1,09	0,98	0,00	1,13	0,96
10	Middle Masseter	0,23	1,18	0,01	0,00	0,00	0,32
11	Inferior Masseter	-0,01	1,12	0,93	0,00	1,10	0,99

Table 2. The differences between the left and right of each population group.

Table 3 shows, seven craniofacial areas, the temporary group had a higher temperature and four lower temperature areas than the permanent group. Whereas on the left side, the highest temperature was indicated by the Left Medial Palpebral Commissure area indicated by the temporary group and the lowest temperature was shown by the Left Middle Masseter area indicated by the permanent group. The craniofacial temperature of left sides in both groups is shown in Table 3 below:

No	Group	Code Area	Temporary Mean	Std. Dev	Permanent Mean	Std. Dev
1	Left Supratrochlear	LST	34,01	0,88	34,50	1,09
2	Left Temporal	LTEMP	34,58	1,00	34,29	1,17
3	Left Medial Palpebral Commissure	LMPC	34,61	0,98	34,53	1,06
4	Left Lateral Palpebral Commissure	LLPC	34,60	0,97	34,42	1,11
5	Left Nasolabial	LN	34,07	0,93	34,55	1,03
6	Left Labial Commissure	LLC	34,16	0,87	34,03	0,91
7	Left TMJ	LTMJ	34,17	0,75	34,47	1,09
8	Left External Acoustic Meatus	LEAM	33,96	1,08	34,11	1,06
9	Left Superior Masseter	LSM	34,05	0,91	34,02	0,93
10	Left Middle Masseter	LMM	34,59	0,99	33,87	0,90
11	Left Inferior Masseter	LIM	34,03	0,91	33,99	0,94

Table 3. Craniofacial temperature of left sides in both groups.

There were eight craniofacial areas on the right, the temporary group which had a higher temperature and three areas where the temperature was lower than the permanent group. Furthermore, the Nasolabial area on the right side of the temporary group showed the highest temperature compared to the permanent group. The craniofacial temperature of right sides in both groups is shown in Table 4 below:

No	Group	Code Area	Temporary Mean	Std. Dev	Permanent Mean	Std. Dev
1	Right Supratrochlear	RST	34,35	0,83	34,34	0,85
2	Right Temporal	RTEMP	34,58	0,99	34,01	0,91
3	Right Medial Palpebral Commissure	RMPC	34,07	0,93	34,54	1,04
4	Right Lateral Palpebral Commissure	RLPC	34,05	0,90	34,28	1,17
5	Right Nasolabial	RN	34,60	0,98	34,50	1,09
6	Right Labial Commissure	RLC	33,94	0,99	34,01	0,93
7	Righ TMJ	RTMJ	34,18	0,75	33,87	0,90
8	Right External Acoustic Meatus	RLEAM	33,96	1,07	33,95	1,08
9	Right Superior Masseter	RSM	34,05	0,91	34,02	0,93
10	Right Middle Masseter	RMM	34,36	0,87	33,87	0,90
11	Right Inferior Masseter	RIM	34,06	0,90	33,99	0,94

Table 4. The craniofacial temperature of right sides in both groups .

Front Side

A total of seven craniofacial frontal areas were observed showing the temporal area of the temporary group and permanent group shows a similar temperature. The craniofacial temperature of front sides in both groups is shown in Figure 3 below:

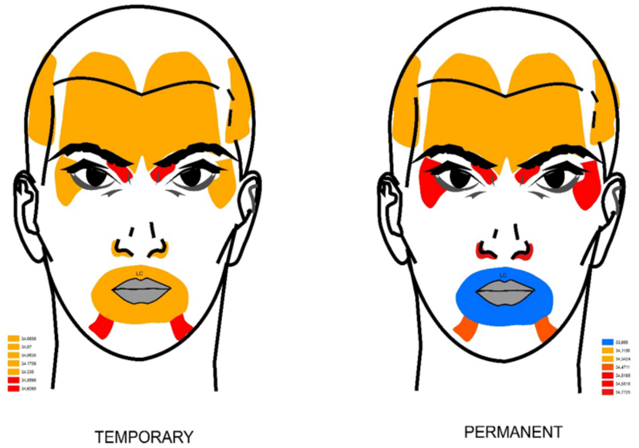

Figure 3. The craniofacial temperature of front sides in both groups.

No	Area	Code Area	Temporary		Permanent	
			Mean	Std. Dev	Mean	Std. Dev
1	Supratrochlear	ST	34,08	0,70	34,12	0,73
2	Temporal	TEMP	34,34	0,84	34,34	0,86
3	Medial Palpebral Commissure	MPC	34,61	0,98	34,52	1,06
4	Lateral Palpebral Commissure	LPC	34,07	0,77	34,55	1,02
5	Nasolabial	N	34,07	0,93	34,77	0,90
6	Labial Commissure	LC	34,18	0,75	33,86	0,91
7	Inferior Labial	IL	34,59	0,99	34,47	1,06

Table 5. Craniofacial scores of front sides in both groups.

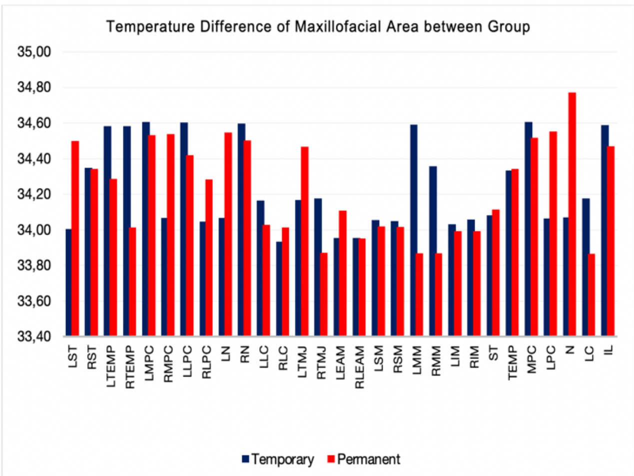

Figure 4. The comparison of temperature either left, right, or front between permanent and temporary groups.
R: Right; L: Left; ST: Supratrochlear; TEMP: MPC: Medial Palpebral Commissure; LPC: Lateral Palpebral Commissure; LC; Labial Commisure N: Nasolabial; IL: Inferior Labial; TMJ: Temporomandibular joint; EAM: External Acoustic Meatus; SM: Superior Masseter; MM: Middle Masseter; IM: Inferior Masseter.

Except for the temporal region, there were three craniofacial areas on the temporary group which had a higher temperature and three areas where the temperature was lower than the permanent group. Furthermore, the Nasolabial area on the front side of the permanent group showed the highest temperature compared to the temporary group. The craniofacial temperature of front sides in both groups is shown in Table 5.

Craniofacial temperature differences between groups

From all the observed areas right, left, and front, the highest temperature was shown by the Nasolabial area on the front side of the permanent group and the lowest temperature was the Labial Commissure on the front side of the permanent group. (Figure 4).

Table 6 shows the results of the T-independence sample criteria analysis, the results of the analysis show that 13 out of 29 areas in the craniofacial area between the temporary and permanent groups showed significant differences ($p \leq 0.05$).

No	Craniofacial Area	Code Area	t-test for Equality of Means	
			Sig. (2-tailed)	Mean Diff
1	Left Supratrochlear	LST	0,00	-0,49
2	Left Temporal	LTEMP	0,01	0,30
3	Right Temporal	RTEMP	0,00	0,57
4	Right Medial Palpebral Commissure	RMPC	0,00	-0,47
5	Right Lateral Palpebral Commissure	RLPC	0,02	-0,24
6	Lateral Palpebral Commissure	LPC	0,00	-0,49
7	Left Nasolabial	LN	0,00	-0,48
8	Nasolabial	N	0,00	-0,70
9	Labial Commissure	LC	0,00	0,31
10	Left TMJ	LTMJ	0,00	-0,30
11	Righ TMJ	RTMJ	0,00	0,30
12	Left Middle Masseter	LMM	0,00	0,70
13	Right Middle Masseter	RMM	0,00	0,49

Table 6. Craniofacial areas showing significant differences.

From these 13 areas, with the results obtained previously that there are significant differences between the left and right between each population group (Table 2), than it is then found that two areas (left and right temporomandibular) in the craniofacial region show significant differences between the permanent and temporary groups.

Discussion

Research that delve temperature differences in craniofacial areas between permanent and temporary populations in the Arctic Zone is still very limited. The application of infrared thermography as a diagnostic tool, for example to identify craniofacial disorders identified from facial temperature, needs to start to explore and evaluate techniques and identification results in a variety of conditions and factors that can affect clinical diagnosis and treatment later.

Results confirms that, the infrared thermography pattern not influence by sex differences. As mentioned by Baker et al.[13], thermal differences between men and women are unclear Cankar and Finderle[14] states no differences were observed in vascular or autonomic nervous system reactivity during the menstrual cycle. Other researcher, Zaproudinas[15], also indicated non-significant sex-related differences in infrared thermography results. However, most studies confirms higher temperatures was also reported for women.[16] Females have better adaptation to environments regarding to subcutaneous fat. Females that have higher fat percentages being more insulated and able to maintain warmer temperatures following cold stimulation.[17] Moreover, the metabolic rate also plays an important role in explaining sex differences to identify abnormalities through infrared thermography. Christensen et al.[18] founds a higher facial temperature in males than females and identified blood circulation and metabolic rate as the main reason for this difference. This effect may be due to a theoretically more prevalent vasodilatation reflex in men.

The infrared thermography known as an excellent tool for visualizing soft tissue infections in humans and can provide a physiological indicator of the underlying disease.[19] Researchers have reported that a temperature difference greater than +3°C indicates the presence of infection.[15] Thus the selection of participants in this study was right, this is indicated by the results of the study which showed that the difference in the mean temperature of the participants was -0.70 to 0.72°C, indicating that the participants were in normal conditions.

This visualization actually relies on the fact that inflammation causes the body to generate heat. As an infrared thermography approach, inflammation is able to detect serious conditions such as infections, injuries, neurodegenerative diseases, and cancers, ranging from acute inflammation to chronic inflammation. The heat generated by the temperature of the tissues or parts detected is associated with changes in microvascular shape and function.[20] Heat sensation in inflammation is caused by increased movement of blood through vessels extending to the extremly cooled environment, resulting the increased of redness.[21] As a result, the temperature of the inflamed area will be higher than the temperature of the surrounding tissue.

The results showed that some of the craniofacial areas of the temporary group had lower temperatures than the permanent areas. This study shows that there is both side-to-side temperature symmetry and asymmetry being observed. All subjects selected were strictly young people with no health problems, thus representing different population groups in the Arctic Zone. The 13 out of 29 areas of craniofacial (45%) were identified as having significant differences between temporary and permanent residents in Arctic Zones. In other words, 55% of craniofacial region temperature either left, right, or front of permanent and temporary groups are similar.

Living in the Arctic Zone, one of which Russia needs the ability to adapt to cold weather.[8] The selection of participants in this study is on the right track. Participants from the temporary group, on average and lived in the Arctic region for less than a year. Obviously, the temporary group participants live ≥19-years in tropical and equatorial countries have a different degree of adaptation to cold than the permanent group. These different adaptations are known to be associated with different synergistic relationships between the cardiovascular and nervous systems between the permanent and temporary groups. The cold-induced increase in heart rate could be associated with decreased vagal activation compared to sympathetic response to cold[22] In addition, exposure to cold causes peripheral vasoconstriction leading to increased systemic vascular resistance and diastolic blood pressure.[23]

Temporary residents living in the Arctic Zone also may experience more seasonal variations in sleep patterns and problems than permanent residents. Other factor relating to the seasonal variation is sunlight. The influence of sunlight is more frequent for infrared thermography applications.[24] This condition can affect a rhythmic biological process known as the circadian rhythm. As is well known, the daily light-dark cycle in the Arctic zone regulates rhythmic changes in human behavior and/or physiology. Studies have found that these changes are regulated by the biological clock, which in humans is located in two areas of the brain called the suprachiasmatic nucleus.[25] In addition, the synchronized circadian cycle depends on light of sufficient intensity and the secretion of melatonin.[26] Thus, factors in Circadian rhythm as a sub-environmental factor known to influence the application of infrared in the Arctic zone deserves attention for future research. In addition, thermographic diagnostic significance based on side-to-side temperature differences is believed to suggest sympathetic nerve dysfunction. The presence of sympathetic nerve dysfunction can be influenced by environmental temperature factors.[27]

However, the left-right results of each population group show contradictory results, for example result of temporal region. This indicates a difference in the sensitivity of the temporal region in each individual, both in the permanent and temporary groups. This is consistent with studies which reported that the asymmetry of pain in the temporal region is one where the symptomatic side is more sensitive than the asymptomatic side.[28] Andersen et.al[29] stated that the temporalis muscle is the muscle most sensitive to pressure. Likewise with other areas such as the nose that show temperature instability. In several studies it has also been confirmed that the skin temperature recorded by infrared thermoraphy is more stable in the nose, but in this study the variation shows that it is highly dependent on several endogenous factors.[27] For this reason, further research involving multi-triggering factors that can affect craniofacial temperature is recommended.

Results showed temporomandibular regions, on the right and left side consistent were identified as having significant differences between groups and also between population groups, these results confirm that can be difficult to use infrared thermography as a diagnostic tool with the aim of identifying and diagnose disorders that occur in the temporomandibular joint of Arctic Zones residents. As is well known, temporomandibular joint disorders are difficult to identify. This difficulty is due more to the complexity of the ethylogic factors and mechanisms of action involving the chewing muscles, the TMJ, and the disc joints.[30] However, most other studies have successfully applied this method to detect pathological abnormalities in the temporomandibular joint.[19] It has been stated that asymptomatic TMJ subjects have symmetrical thermal patterns with mean values of 0.1°C. Whereas subjects suffering from TMJ pain were found to have asymmetrical thermal patterns with increased temperature over the affected TMJ region with mean values of 0.4°C.[28] As long as difference in the mean temperature of the TMJ region of participants was -/+0.30°C, indicating that the temporomandibular regions were in normal conditions. Despite Zaproudina et al.[15] stated temperature measurement in forehead and cheek of healthy individuals demonstrated good reproducibility, further studies are needed to determine the reproducibility of identification data to detect pathological abnormalities in the temporomandibular joint using this method.

Conclusions

Some of the craniofacial areas of the temporary group had lower temperatures than the permanent residents of Arctic Zone. Environmental, is one of disadvantage factor needs accounting that may influence application of infrared thermography method to detect pathological abnormalities in the craniofacial areas of Arctic Zones residents. It can be difficult to use infrared thermography as a diagnostic tool with the aim of identifying pathological abnormalities in craniofacial of the Arctic Zone population, particularly temporomandibular joint area.

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Declaration of Interest

The authors report no conflict of interest.

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