Trends in the Incidence of Ischemic Heart Diseases and its Association with Low Air Temperatures in the Circumpolar Region

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Abstract. Low air temperatures in the circumpolar region have a negative impact on human health. Cardiovascular disease (CVD) is the leading cause of death worldwide. According to our study, mortality from CVD is higher in the circumpolar region than in more southern latitudes. The first part of our study was devoted to experiments on diving reflex. The experiment involved 25 people aged 20-30 years. We found that immersing a person's face in cold water leads to an increase in heart rate (heart rate). The second part of our study was to identify the correlation between the daily low air temperature and citizens' requests for medical care due to ischemic heart disease (ISD) in the Arkhangelsk region, Russia (2013-2018). We studied groups of 5869 adults of working age (18-60 years) and 45812 adults older than working age (60+). For the able-bodied population, the correlation mentioned above was extremely weak. This is due to the good adaptation of the body to lower ambient temperature. For the population older than the working age, the correlation was stronger. This is due to a decrease in body adaptation to temperature reduce.

1. Introduction

Global climate change of the planet, along with such threats to international security as a nuclear disaster, terrorism, cybercrime, environmental and financial-economic crises are a new challenge to humanity at the turn of XX–XXI centuries [1]. Problems emerging due to the impact of temperature waves in the circumpolar region, especially ones close to the Arctic, bioecosociosphere and public health are of special concern of all social institutions of a society [2].

Arkhangelsk region is a Northern territory of Russia that accumulates a combination of different risk factors such as climatic, natural and geographical, ethnic, environmental, and social. Territories of Arkhangelsk region and Nenets Autonomous Region are exposed to extreme hydro-meteorological conditions, directly or indirectly affecting human health, such as extreme frosts, heavy precipitation in form of rain, strong winds, and river floods during high-water periods.

Long lasting frosts (of duration more than 3 days with minimum temperatures below -35°C) and extremely low temperatures (below -45°C) are the most specific for the Eastern half of the Arkhangelsk region and continental areas of Nenetsk Autonomous Region. Annually there are from 6 to 10 days in a row with frosts of below -35°C. And climate change can be accompanied by a change in the dynamics of natural hazard repetitions which can have unobvious latent nonlinear nature [3,4].

Current climate change can be characterized by significant regional heterogeneity of abnormal behavior, including the Arkhangelsk region [4,5]. As a result, there is a situation when the current state...
of the regional climate system and regional ecosystems cannot be "approximated" even from the nearest past 5-10 years [3,6]. So, losses from uncollected observations on the biological system state become irreplaceable for scientific understanding of the evolution logic, and research on their collection and storage has attained high relevance [6].

That determines the strategic direction of research within the development of the Northern (Arctic) Federal University named after M. V. Lomonosov (NARFU) scientific and educational project “Arctic biomonitoring laboratory” [7].

Cardiovascular diseases (CVDs) is the number one cause of death worldwide. Seasonal variation in morbidity and mortality due to CVDs has been noted in both the northern and southern hemispheres, with higher incidence rates during the winter than in the summer. This variation linked to multiple risk factors, such as temperature, physical activity, air pollution, infections, and food habits [8,9].

Consider mortality data from Ischaemic heart disease (group I20-I25 [10]) in Europe according to the World Health Organization [11]. We have identified 3 groups: from 0 to 64 years old, from 60 to 74 years old and over 65 years old (see figure 1). The figure contains the number of deaths from Ischaemic heart disease per 100,000 population.

Figure 1. Trends in mortality due to Ischaemic heart disease in the European Union until may 2004 (EU) and Northern Europe (NORDIC).

Figure 1 shows that mortality in the EU has reduced in general. This is due to the improvement of the health care system and the prevention of cardiovascular diseases among the population. We have noticed a significant difference in mortality rates for people over 65 years of age among the European Union and the Nordic countries. In the group of people 0 - 64 years old there is no difference. In the group of people 60 - 74 years old there is a noticeable slight difference.

The Nordic countries differ from other countries in more severe weather conditions, in particular, lower air temperatures. We hypothesize that the adaptive mechanisms of older people work less effectively, which in the cold season leads to an increase in mortality from Ischaemic heart disease.

2. Experiments and methods
When a person leaves the warm house at the freezing season, the dramatic change in temperature primarily affects open areas of a body: face and hands. A person instinctively holds his breath. We assumed that this effect is similar to the diving reflex that occurs when a person is immersed in water. The effect of low temperature on the face while holding breath causes a change in the heart work. The
study [12] concludes that cold stimulation of the face is a more effective method than immersion of the hand in the water.

2.1. The study of diving reflex.
The purpose of this study is to determine the effect of temperature parameters on the change in heart rate (electrocardiogram) of students when immersing face in the water.

The experiment involved students of the Northern (Arctic) Federal University aged 20 to 30 years, of different studying programs. The study did not involve athletes. All participants of the experiment gave their voluntary consent to participate in the study.

Measurements were carried out using the integrated installation "BIOPAC system MP35" [13]. Equipment for the study: the main data acquisition unit MP35, a set of electrode wires BIOPAC (SS2L) and vinyl electrodes, also for the experiment there were needed a shallow bath filled with ice water, a thermometer and a personal computer (figure 2).

![Figure 2. Experimental installation](image)

(1-monitor, 2-MP35, 3-electrodes, 4-bath with water and ice).

The BSL PRO option for advanced analysis was used for the study. A set of SS2L electrode wires was connected to the data collection unit MP35 by means of output CH1, then the electrodes were connected to the wires according to the diagram (figure 3).

On the right wrist there is a white electrode ( "-"), on the left wrist there is a red electrode ( "+"), and on the right ankle, there is a black one (grounding).

The experiment was conducted in a sitting position. The subject's face should remain submerged for at least 20-30 seconds.

The main experiment involved 25 people, but only 18 were used for data processing due to some features of the subjects. The research methodology was built in 4 stages.
The first stage is a calm state. At this stage, the subject was asked to take a position of "sitting" in the chair, in a comfortable position until the heart rate is stabilized; it took 3-5 minutes. At that time, the subject was asked to read the main instructions and electrodes were getting fixed. After that, the background state of the ECG was measured.

The second stage is the effect of apnoea. Here the subject needed to hold his breath. Taking the electrocardiogram began in advance to give the computer time to display the data.

The third stage is the influence of cold water. At this stage, the test subject had to immerse the face in cold water at a temperature of ~5°C, for at least 30 seconds.

The fourth stage is the effect of water at room temperature. The test subject had to immerse the face in water at a temperature equal to the room, in our case ~19°C, for the same time as in the previous stage.

After each stage, except for the first one, the recovery time was given, which was 3-5 minutes. The obtained electrocardiograms were processed in BSL Analysis 4.1 (figure 4).
The main interest of this study was heart rate (HR).

2.2. Research according to long-term observations

We used the database already described in [14]. The database combines data on the incidence of the population of the Arkhangelsk region since 2013 and data on the daily meteorological situation. We use weather data of the time 6:00 am for the study of cardiovascular disease as at this time the most common critical conditions for myocardial infarction and coronary heart disease take place.

We studied groups of 5869 adults of working age (18-60 years) and 45812 adults older than working age (60+).

Obtained results were transferred from the database to MS Excel 2010 [15], in this program numerical graphs were built, after which the data was processed in the statistical software IBM SPSS Statistics [16].

The following statistical methods and test were used in this research:
1. Preliminary preparation of data for processing was carried out to check for the presence of extreme values, construction of distribution diagrams, check for normality using the Shapiro-Wilk test.
2. The dependence of the compared samples was proved by means of correlation analysis with the construction of dispersion diagrams, calculation of the correlation coefficient $p$-Spearman (for abnormal distributions).
3. Small samples were compared using nonparametric criteria: $\chi^2$ Friedman test for comparison of three and more dependent samples, Wilcoxon signed ranks test for pairwise comparison of dependent samples.

3. Experimental results and discussion

3.1. The results of the diving reflex study.

After processing the primary data, the following dependence of the average heart rate on the time spent in water (figure 5) for all subjects was revealed.

![Figure 5. Distribution graph of the average heart rate for all subjects relative to the time interval from 0 to 30 seconds.](image)

After analyzing the graphs, you can see the following relationship:
- in a calm state and with breath held, the heart rate practically does not change over time;
at ~19°C after immersion in water, the heart rate first increases, then decreases, but remains within the norm of 60-80 beats per minute;

— when the face is immersed in cold water ~5°C there is a dramatic increase in heart rate up to 92 beats per minute (tachycardia), and then a rapid decrease to 50 beats per minute (bradycardia).

Some subjects' heart rate reached 125 beats per minute when immersed in water, and some subjects had the heart rate only 18 beats per minute at the end of the test. We conducted tests on young healthy students. Conducting the experiment on elderly people were refused by us, as it could provoke a heart attack.

We conducted further analysis in IBM SPSS Statistics Standard, which did not refute the hypothesis that exposure to cold causes a sharp change in heart rate.

### 3.2. The results of the analysis of long-term observations.

We analyzed the number of people having a diagnosis of Ischaemic heart disease (group I20-I25) called for medical aid in the Arkhangelsk region (figure 6) for 2013-2018. It should be noted that the number of appeals of working age people of 18-60 years is 10 times lower than the number of appeals of people aged 60+. The chart shows that the number of calls is higher than the average ones in January, February, March, and October, rather a high amount of calls is in November and December. The average air temperature these months is less than 5°C (figure 7). It can be preliminary concluded that the number of calls for medical aid due to ischaemic heart disease is the highest in months when the air temperature is less than 5°C.

We conducted a frequency analysis and made a frequency distribution of calls number having a step of 5°C in the range from -50°C to 25°C (figure 7). This annual temperature range is the most frequent in the last decade. The analysis showed that the most frequent patients seek help in the temperature range from -15°C to 15°C. It was in this range that we observed the dramatic change of the heart rate of the subjects when studying diving reflex. The transition from high room temperature to low outside temperature causes patients the same condition as observed when swimmers immerse in cold water.

![Figure 6. The chart of the incidence of Ischaemic heart disease.](image-url)
If the ambient temperature is low and, accordingly, the surface of the skin is cold, the blood returns to the heart through deep veins. If the veins are healthy, heart problems when having a dramatic change in heart rate does not occur. But people 60+, as a rule, have veins which are not always in good condition. At low temperature, there is a narrowing of the blood vessels. In addition, people 60+ have increased blood viscosity, which increases even more with decreasing temperature. As a result, vascular patency in the body deteriorates. Consequently, blood pressure increases. Along with a sharp change in heart rate, an attack occurs. The patient seeks for medical aid.

The maximum is observed at a temperature of -5°C. At colder times, at temperatures below -15°C, older people rarely leave the room, so the number of attacks is reduced.

In the temperature range -5°C-0°C diving reflex appears most often when leaving a warm room for cold outside.
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