Effects of moderate- to high-level physical performance on blood levels of cardiac biomarkers in extreme conditions of Antarctica

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Abstract

The aim of this study was to examine the effect of extreme climatic conditions (particularly cold) on levels of cardiac biomarkers after moderate- to high-level physical performance in members of the 6th and 7th Czech Antarctic Scientific Expeditions during their field work in Antarctica. A study evaluating performance-related changes in levels of cardiac biomarkers in extreme conditions of Antarctica. A total of 35 venous blood samples were collected and analyzed from 17 subjects. The first series of blood samples were collected prior to physical performance, the second 8 to 12 hours post-exercise. The third series of samples were collected only in those subjects where pathological values were detected previously. In 1 subject (12.5%), an increase in NT-proBNP level lasting 24 hours was present after physical performance. Interestingly, none of the individuals had a rise in TnT and DD blood levels following physical exertion. We didn't find changes in TnT and DD blood levels comparable with changes reported in athletes after a marathon. In only one subject, transitional elevation od NT-proBNP was present. This finding might be due to protective effects of cold on cardiac cells. The effects of physical performance and of work in polar regions should be better investigated in future studies.

Key words: *cardiac biomarkers*, *physical performance*, *Antarctica*, *extreme environment*

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Introduction

Cardiac troponins T and I (TnT and TnI) are regulatory proteins present in the contractile apparatus and in the cytoplasm of cardiac cells. These proteins are used in clinical practice as a biochemical marker of myocardial infarction (gold standard). N-terminal fragment of pro-brain natriuretic peptide (NT-proBNP) and B-type natriuretic peptide (BNP) are biochemical markers of acute heart failure, with a high sensitivity and specificity. D dimers (DD), fibrin degradation products, are used in the clinical practice to diagnose thromboembolic disease (TED).

Dozens of papers have demonstrated performace-related elevation of troponin T, NT-proBNP, ultrasensitive TnT and D-dimer (DD) levels in peripheral blood after a high to extreme physical exertion in endurance athletes (*e.g.*, completing a marathon, triathlon, endurance cycling etc.) (Sumann et al. 2007, Mingels et al. 2010, Shave et al. 2010, Lippi et al. 2011, Scherr et al. 2011, Parker et al. 2012). These findings can lead to potential diagnostic problems in clinical practice. It is not yet known whether the elevation of cardiac biomarkers may occur even after rigorous physical activity or after challenging work in the polar regions. Furthermore, there is no evidence on how these findings are modified by cold exposure and associated extreme weather conditions of the polar regions.

This topic became the subject of our research during two stays at the Czech polar station of J. G. Mendel (Mendel base), Antarctica, during Antarctic summer seasons 2012 and 2013. To our best knowledge, no reports have been published on exercise-related elevations of cardiac biomarkers and DD in the polar regions.

Material and Methods

We present the results of the first study on the effect of physical activity on blood levels of troponin T, NT-proBNP and DD after physical performance in the extreme environments of Antarctica.

We hypothesized that - similarly to athletes - transient elevations of blood levels of TnT, NT-proBNP and DD might be present in the members of glaciological team after the demanding work in the Antarctic setting.

Furthermore, we hypothesized that cold climatic conditions in Antarctica may modify (decrease) the frequency of this phenomenon (*e.g.*, by protective effect of cold on cardiac cells).

Background

The construction of Mendel base was completed in 2007. The station is summer-operated only and is located on James Ross Island, east of the Antarctic peninsula. Coordinates of the station are 63°48'05.06"S 57°53'09.07"W, altitude 9 m.a.s.l.. Main activities include scientific research on climate change, glaciology, geology, biology of lower plants, bacteriology and others. The 6th Czech Antarctic Scientific Expedition (CASE) (December 2011 to March 2012) consisted of 13 people, including 11 scientists and 2 technicians. The 7th CASE (January to March 2013) consisted of 17 scientists and 3 technicians. In both seasons, a physician was also a member of the expedition (the first author of this article). During their stay in Antarctica, most of the scientists work in the field for several hours a day. During this time they often walk distances up to tens of kilometers and overcome elevations of up to several hundreds of meters.

Temperatures on James Ross Island during Antarctic summer season range from +5°C to -15°C. However, the main factors influencing thermal comfort in this area are wind speed (wind chill factor) and high relative humidity. For an overview of the meteorological conditions during the stay at Mendel base (recorded by the station meteorologist) *see* Figs. 1 and 2.

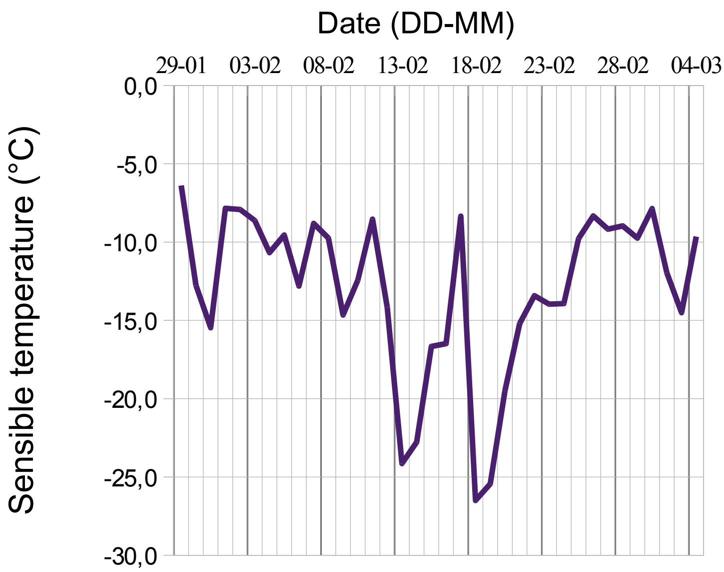

Fig. 1. Minimum Sensible Temperature calculated from temperature recordings from Mendel base, James Ross Island, Antarctica (2012 Antarctic summer season).

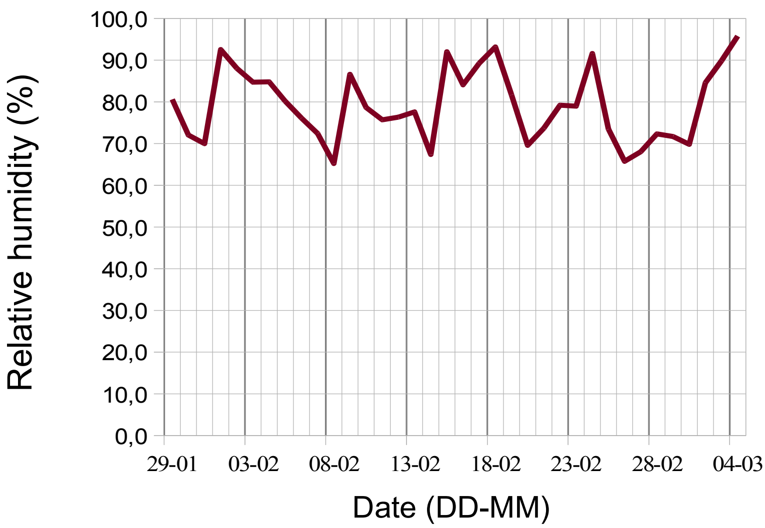

Fig. 2. Relative Humidity recordings from Mendel base, James Ross Island, Antarctica (2012 Antarctic summer season).

Subjects

The participants of the 6th and 7th CASE were asked to join this study. The single inclusion criterion was to complete an at least 25km walk per day during scientific field work. This criterion was best met in glaciologists, since they were studying two glaciers located approximately 15km away from Mendel base. On the way to the glaciers (and back to the station), elevation of around 1000m in total and a challenging terrain had to be faced. Along with the fact that each team member carried a backpack with ca 10 kilograms of equipment and material, we classified this physical activity as moderate- to high-level, performed at (estimated) 7-8 METs (metabolic equivalent) (Compendium-Web sources). For comparison, running a marathon is a physical activity at about 10 to 13 METs – strongly depending on running speed (Compendium-Web sources).

A total of 17 subjects had voluntarily participated in our study. All the subjects were of Caucasian race, 3 women and 14 men aged 25-48 years (mean 28.8 years, median was 30 years). None of the subjects was treated for any cardiovascular disease, none was taking any regular medication. Before leaving for Antarctica, all of the subjects completed a comprehensive medical examination with the conclusion that they all were healthy and able to participate in the expedition. The fitness and the physical training of the subjects were not examined.

Laboratory analyses

Two series of venous blood samples were collected from each subject -- the first series before physical activity and the second 8-12 hours post-activity. Thus, the kinetics of blood level elevation of TnT, NT-proBNP and DD during cardiovascular events were respected (Scherr et al. 2011).

The third series of samples (at 24 hours after the second series of samples) were collected only from those subjects where an elevation of one of the markers had been found previously.

Two milliliters of venous blood were collected into test-tubes with ethylenediaminetetraacetic acid. The blood samples were immediately analyzed on a portable biochemical analyzer Cobas H 232, Roche Diagnostics. Blood samples were collected and all laboratory tests were performed on Mendel base; indoor air temperature was usually 16-22°C. The laboratory analyses were performed in accordance with the manufacturer's recommendations.

Cut-off values (as indicated by the manufacturer) for each marker are: TnT - 0.03 ng/ml - for myocardial infarction, DD - 0.50 µg/ml - for TEN and NP-proBNP - 125 pg/ml - for acute heart failure.

Results

Altogether, 35 samples of venous blood from 17 subjects were analyzed. NT-proBNP levels were measured in a total of 8 subjects. In the first series of blood samples, the level of NT-proBNP was normal (below 60 pg/ml) in all subjects. In the second series of samples (8-12 hours after physical performace), an elevation to 90 pg/ml was detected in one case (12.5%). This blood sample was received from a 25-year-old man, who did not show any clinical signs of acute heart failure and whose blood pressure and heart rate were normal. Twenty four hours later, control blood sample was taken and analyzed in this subject. The analysis showed a decrease of NT-proBNP level to the original values (*i.e.*, below 60 pg/ml).

Blood level of TnT was measured in a total of 12 subjects and DD levels were analyzed in 10 subjects. None (0%) of the studied subjects had performance-related TnT or DD elevation above the detectable limit. This finding was surprising and might be important. A summary of results is presented in Table 1.

Subject number	**TnT 1**	**TnT 2**	**TnT 3**	**DD 1**	**DD 2**	**DD 3**	**NT-proBNP 1**	**NT-proBNP 2**	**NT-proBNP 3**
1	< 0.03	< 0.03	X	X	X	X	X	X	X
2	< 0.03	< 0.03	X	0.20	0.22	X	X	X	X
3	< 0.03	< 0.03	X	0.10	0.11	X	X	X	X
4	< 0.03	< 0.03	X	0.11	0.13	X	X	X	X
5	< 0.03	< 0.03	X	0.11	0.11	X	X	X	X
6	< 0.03	< 0.03	X	0.34	0.43	X	X	X	X
7	< 0.03	< 0.03	X	0.14	0.15	X	X	X	X
8	< 0.03	< 0.03	X	0.14	0.14	X	X	X	X
9	< 0.03	< 0.03	X	< 0.10	0.11	X	X	X	X
10	< 0.03	< 0.03	X	< 0.10	< 0.10	X	< 60	< 60	X
11	< 0.03	< 0.03	X	0.21	0.22	X	< 60	< 60	X
12	< 0.03	< 0.03	X	X	X	X	< 60	< 60	X
13	X	X	X	X	X	X	< 60	< 60	X
14	X	X	X	X	X	X	< 60	< 60	X
15	X	X	X	X	X	X	< 60	**90**	< 60
16	X	X	X	X	X	X	< 60	< 60	X
17	X	X	X	X	X	X	< 60	< 60	X

Table 1. Results of all blood tests performed in 17 subjects total.

TnT 1 – troponin T test, first blood sample (before physical performance)
TnT 2 - troponin T test, second blood sample (taken 8-12 hours after the end of physical performance)
TnT 3- troponin T test, third blood sample (taken 24 hours after 2nd blood sample)
DD 1- D-dimer test, first blood sample (before physical performance)
DD 2- D-dimer test, second blood sample (taken 8-12 hours after the end od physical performance)
DD 3- D-dimer test, third blood sample (taken 24 hours after 2nd blood sample)
NT-proBNP 1 - NT-proBNP test, first blood sample (before physical performance)
NT-proBNP 2 - NT-proBNP test, second blood sample (taken 8-12 hours after the end od physical performance)
NT-proBNP 3 - NT-proBNP test, third blood sample (taken 24 hours after 2nd blood sample)
X – test not perfmormed
Pathological values are indicated as **bold**.
Cut-off values (according to the manufacturer of the biochemical analyzer): DD: 0.50 µg/ml; TnT: < 0.03 ng/ml – low risk, 0.03–0.1 ng/ml – medium risk, > 0.1 ng/ml – high risk; NT-proBNP: Patient age < 50: > 450 pg/ml. NT-proBNP normal value (for men of age 18-44): 27.7 ± 25.5

Discussion

Recent decades saw a significant increase in human activities in the polar regions. These include scientific activities, development of tourism and of mining and other industries. Moreover, novel sport events take place in the polar regions. The increased human presence also means a risk of a higher incidence of health problems. It is therefore important to know the physiology and adaptation processes of the human body to extreme conditions of polar regions.

The findings of performance-related elevations of cardiac biomarkers after extreme physical performance in endurance athletes are well documented. Abnormal blood levels of these markers can be detected within a few hours post-performance, decreasing within 72 hours to the physiological values in most subjects. (Mingels et al. 2010, Shave et al. 2010, Lippi et al. 2011, Scherr et al. 2011). Elevated blood levels of TnT after long-distance walks (*i.e.*, a medium- to high-level physical activity) have also been reported, though in a smaller percentage of subjects than after extreme physical exertion (Eijsvogels et al. 2010). The significance of these findings is currently discussed among health care professionals. Most authors assume that the elevated blood levels of cardiac biomakers are non-specific and rise due to increased permeability of the cell membrane or altered metabolism of cardiac cells during performance (Shave et al. 2010, Lippi et al. 2011). The effects of fitness and a of exercise intensity have been assessed (Scharhag el al. 2008, Mingels et al. 2010, Legaz-Arrese et al. 2011). Most authors assume that no damage to the myocardial cells is present during performance (Shave et al. 2010, Lippi et al. 2011, Scherr et al. 2011).

However, some authors suggest the presence of a minimum amount of myocardial necrosis during extreme exertion (Harper 2010). Performance–related diastolic dysfunction, left ventricular dysfunction and hypertrophy of the right ventricle after extreme physical performance were also reported (Neilan et al. 2006, Ector et al. 2007, Dawson et al. 2008, Harper 2010). A development of chronic microstructural and functional changes (arrhythmias) due to repeated extreme physical exertion were reported (Ector et al. 2007, Harper 2010).

Physical performance also increases the activity of the blood coagulation system. A number of studies demonstrated an increased procoagulant activity or even elevation of blood level of DD to pathological values typical for TED. Performance-related increase in the incidence of TED was reported in endurance athletes (Sumann et al. 2007, Parker et al. 2012).

As already mentioned, the level of physical performance ranges between 10 to 13 METs in marathon runners (Compendium-Web sources). It is not well known whether performance-related elevation of cardiac biomarkers may occur even at lower levels of physical exercise (*e.g.*, long-distance walks in rough terrain) or during demanding physical work.

Currently, it is not known how these findings are modified by cold. From several epidemiological studies and from clinical practice it is known that cold increases the risk of myocardial infarction (Bhaskaran et al. 2010). Effect of whole-body cooling has not been demonstrated consistently across physiological studies. A lot of questions remain to be answered in future studies.

The diagnostic accuracy of the used TnT assay was very good (cut off values < 0.03 ng/ml). Nonetheless, even more sensitive TnT assays are available (*e.g.* ultrasensitive TnT assays) with cut off values down to 0.012 ng/ml. However, their potential use in Antarctica is very limited mainly due to difficult logistics.

Conclusion

The results of our study show that a moderate- to high-level of physical activity in the polar regions may affect levels of NT-proBNP in the blood. The result why we didn't found such a finding in even more subjects (also for TnT and DD) can be explained in two different ways.

One possibility is that the cold weather with sensible temperatures below -10°C during physical activity has a protective effect on myocardial cells.

The second possibility is that the level of physical performance was not high enough to cause a significant increase in cardiac biomarkers.

This research should be continued. The future studies in similar (or even harsher) climatic conditions should be performed under more standardized conditions and at higher levels of physical activity. These attributes are best met in the participants of sport events such as South Pole Marathon, North Pole Marathon, Arctic Circle Race (cross-country ski race in Greenland), ski crossings of Greenland, Antarctica etc.

Likewise, it would be very interesting to carry out this research with persons performing physically demanding work in the polar regions (*e.g.*, field workers of mining companies or oil industry workers in Arctic Russia or Canada).

The limitations of this study were: small number of studied subjects, our inability to determine the level of physical exertion in the studied subjects and the relatively lower diagnostic accuracy of the troponin T assay.

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