Changes in immunological characteristics of summer crew during a short term expedition to Antarctica

Alena Žákovská[1,2*]

[1]*Section of Animal Physiology and Immunology, Department of Experimental Biology, Faculty of Science, Masaryk University, Campus Brno-Bohunice D 36, Kamenice 753/5, 625 00 Brno, Czech Republic*
[2]*Department of Biology, Faculty of Education, Masaryk University, Poříčí 623/7, 603 00 Brno, Czech Republic*

Abstract
The aim of this study was to examine the effect of extreme climatic conditions and isolation on levels of pre-selected immunological parameters in humans. This article describes changes in immunological parameters measured in members of the 9th Czech Antarctic Scientific Expedition during their field work in Antarctica in summer time. The total of 15 sera samples were collected in the morning shortly before the expedition, the second collection was proved in the middle and the third in the end of stay at the Czech Polar station (Mendel station). The statistically significant difference appeared in eight of 11 parameters, from which the value of C3, C4, IgA, and number of monocytes decreased; level of IgG and number of non segmented neutrophils increased. The difference was showed also in the middle of stay, when the level of IgM, number of neutrophils and lymphocytes in the first part of stay decreased, in the second increased. The way of life in the station, physical performance and extreme climatic condition, probably positively affected the results of some studied immunological parameters.

Key words: Antarctica, extreme environment, austral summer, expedition, Mendel station, immunoglobulins

DOI: 10.5817/CPR2023-1-11

Introduction

Antarctica is a continent with the most extreme climate (Turner et al. 2009, Muller et al. 1995b). The continent is inhabited only by temporary residents mostly constisting of scientists and support personnel. Long-term stays in Antarctica (or generally in the polar regions) may have signifiant impacts on human health. Extreme cold, high levels of ultraviolet radiation, magnetic field disturbances, major differences in circadian cycle and extreme isolation are the main stressors in this area.

Several studies of immune changes in humans during long-term isolation have

Received April 20, 2023, *accepted* August 2, 2023.
*Corresponding author: A. Žákovská <zakovska@ped.muni.cz, alenazak@sci.muni.cz>
Acknowledgements: The study was financially supported by specific research of Masaryk University (MUNI/A/1258/2022).

been performed, most of them took part in Antarctica and on the International Space Station (*e.g.* Rykova et al. 2006, Stratis et al. 2023). These studies revealed that during long-term stays in isolation and in extreme environmental conditions, multiple changes in the immune system may develop. Some changes were observed also during short-term stays in the polar regions.

Cell-mediated immune responses in relation to long-term isolation have been a part of long-term medical research programme of ANARE (Australian National Antarctic Research Expedition). The australian authors have monitored immune responses of Australian winter-over groups on Antarctic and sub-Antarctic research stations during 1984-1992 period and found overall decrease in cell-mediated immune response by 36% (hypoergy). The underlying mechanisms of this finding were unclear (Muller et al. 1995a, Williams et al. 1986) and studied by Australian authors furhter. Tingate et al. (1997) have published the results of a long-term research. The authors reported the alterations in T-cell function, significant reduction in T-cell proliferation in response to phytohaemagglutinin, reduction in serum levels of pro-inflammatory cytokines and reactivation of latent herpesviral and Epstein-Barr-viral infections have been observed in winter-over Australian Antarctic expeditioners.

The effect of long-term isolation and extreme environmental conditions on humoral immune response in humans has been the object of a few studies by Muller et al. (1995a,b), Mishra et al. (2011, 2014) and Yadav et al. (2012). Immunoglobulines are one of the most important components of the immune system. Alterations in serum immunoglobulin levels may decrease the susceptibility to infectious diseases. In the study by Mishra et al. (2011), serum IgA has been assessed as a possible biomarker of environmental stress. The authors observed increase in IgA and decrease in IgG serum levels during a 1-month ship journey to Antarctica and the same pattern during the 2-month stay at Maitri research station, Antarctica (Mishra et al. 2011). The authors stated that one month may be a sufficient period for the development of impaired immune responses in relation to isolation and environmental stress (Mishra et al. 2011). Another study performed at Maitri station confirmed increase in serum IgA, interferon gamma and TNFalpha during different periods of Antarctic winter in participants of the 28th Indian Antarctic Scientific Expedition (Yadav et al. 2012). In both Indian studies, levels of IgM showed no changes during Antarctic residence. The possible explanation for in increases serum IgA level during the isolation period is the role of hypothalamic-pituitary-adrenal axis in response to the environmental stress (Yadav et al. 2012). In contrary, Shearer at al. (2001) have evaluated the effect of an 8-month period of isolation on primary (IgM) and secondary (IgG) antibody responses to bacteriophage ΦX-174 at the Australian Antarctic station Casey. The expeditioners showed no signs of defective antibody responses during the stay in Antarctica (Shearer et al. 2001).

Mucosal imunity has been examined as a part of Australian Antarctic medical research programme in the 1990s. Francis et al. (2002) and Gleeson et al. (2000) have observed temporary decreases in serum IgA and IgM levels in different periods of year during long-term stays of personnel wintering at Australian Antarctic stations Mawson, Davis and Casey. Importantly, decreased salivary concentrations of IgA and IgM are associated with impaired mucosal immunity and higher risk of acquiring respiratory infection (Gleeson and Pyne 2000).

Further immunological research in Antarctica was focused on reactivation of latent viral infections during periods of long-term isolation. In most of the studies, increased frequency of herpesviral and Ep-

stein-Barr viral infections have been observed after long-term residency in Antartica (Muller et al. 1995b, Tingate et al. 1997).

Majority of the Antarctic studies on changes in immune system have been performed during Antarctic winter or even one-year-long periods of isolation at research polar stations. The aim of our study was to assess the effect of a 2-month stay (during Antarctic summer) at a research station in Antarctica on 11 pre-selected immunological parameters.

Material and Methods

Background (site decription)

Mendel research station is a summer-operated Antarctic facility owned and run by Masaryk University, Czech Republic. The station is situated at the northern coast of James Ross Island, Antarctica, coordinates of the station are 63° 48' 05.06" S, 57° 53' 09.07" W, altitude 9 m a.s.l. (Prošek et al. 2013). Scientific research programme is focused on climatology, geology, paleontology, glaciology, biology of lower plants, microbiology and others. The 9th Czech Antarctic Scientific Expedition (CASE) took part between December 2014 and February 2015. Twelve scientists and 3 support personnel participated in the expedition. The outside air temperature (AT) on James Ross Island during the stay in Antarctica was AT_{max} 9.3°C, AT_{min} -4.4°C and AT_{mean} 0.8°C. Measured ground radiation (GR) during the stay was GR_{max} 1028 W.m^{-2}; GR_{mean} 219 W.m^{-2}. Maximum recorded wind speed (WS) was 22.1 m.s^{-1}, WS_{mean} was 4.6 m.s^{-1} (Kavan et al. 2016).

Subjects

Fifteen healthy subjects – participants of the 9th Czech Antarctic Scientific Expedition were included, of these 3 women and 12 men. Age of the participants ranged between 25 and 61 years (mean 37.9 years, median 35 years), mean Body Mass Index (BMI) was 25.36 (± 3.55). All the subjects were healthy, none of the subjects was using any regular medication. For most of the expeditioners, the daily program usually included several hours of field work along with several hours of laboratory work.

Laboratory analyses

The procedures of pre-departure and during-Antarctic stay were identical. Blood samples have been collected in 3 series from the antecubital vein using one S-Monovette tube (plasma gel, 7.5 ml) (Sarstedt, Prague, Czech Republic). The first series were collected in the Czech Republic between December 23rd and 29th, 2014 (pre-departure), the second series after the first month of the Antarctic stay (on January 20th, 2015) and the third series before the end of the stay in Antarctica (on February 10th, 2015). Of the 45 collected samples, sera were separated and frozen at -20°C, as partially described by Žákovská et al. (2015).

Hematocrit and leucocrit were evaluated using the Bürker chamber in the laboratory of Mendel research station, Antarctica. Blood differential tests were performed

by counting subtypes of white blood cells (WBC) from peripheral blood using a microscope. A drop of blood from the sample was put on a glass slide and the Pappenheim staining was used. In the blood differential, numbers of polymorphonuclear neutrophils, immature band neutrophils, lymphocytes, monocytes, eosinophiles and basophils were counted.

Serum levels of C-reactive protein (CRP), immunoglobulins M, G and A (IgM, IgG, IgA) and of complement components C3 and C4 were assessed using reagent sets (BioSystems S.A., Barcelona, Spain) and ELISA reader (turbidimetric method) Rainbow (SLT Instruments, Oxford, UK). The blood samples taken in Antarctica were analyzed directly at Mendel research station.

Research within the project proceeded in accordance with the law (No. 96/2001 Coll. M. S. on Human Rights and Biomedicine and Act No. 101/2000 Coll. Privacy).

Ethical approval

Ethical approval for the study was obtained from the Ethical committee of the Faculty of Science, Masaryk University, Czech Republic and Ethical committee of University Hospital Brno, Czech Republic. Written informed consent was obtained from each studied subject.

Statistical analyses

For each parameter, mean values, their standard deviations (SD) and medians were calculated. Paired t-test was used to compare data from the Czech Republic and from Antarctica. Results were considered to be statistically significant if $p < 0.05$.

Results and Discussion

Changes in immunoglobulin A, M, G as well as blood characteristics evaluating the differences between initial state, *i.e.* data recorded before the Antarctic expedition and the two check points during the expedition stay at the Mendel Antarctic station (January 21st and February 10th, respectively) are summarized in Table 1. General trends in these parameters are shown in Fig. 1. In all expedition members, IgM in the second part of stay and IgG in the first part of stay showed increasing trend (Fig. 1), while IgA decreased with time of stay at the Mendel station.

Similarly to immunoglobulins, C3 and C4 complements decreased with the expedition time at Mendel station and showed the differences (between the state before the expedition and second checkpoint, *i.e.* February 10th) described below: Level of C4, C3 complement, concentrations of IgA ($p < 0.01$), IgM ($p < 0.05$), and IgG ($p < 0.01$).

Statistically significant differences were found in 2 out of the 6 tested parameters related to urine (the pH value and the number of leukocytes in 1 µl of urine – Žákovská et al. 2015). In recent study, we have found statistically significant differences in the values of HDL cholesterol and uric acid. Statistically significant differences were, however, not observed in the values of total cholesterol, triglycerides, BMI, weight, energy, and meat intake (*c.f.* data from Žákovská and Zezulová 2016).

Parameter	Before	CH 1	20.1.	CH 2	10. 2.	CH 3
C3 [$g.L^{-1}$]	1.10 (0.59)	*	0.32 (0.02)		0.66 (0.21)	**
C4 [$g.L^{-1}$]	0.34 (0.06)		0.36 (0.11)	**	0.27 (0.04)	**
Immunoglobulin A [$g.L^{-1}$]	0.66 (0.12)	**	0.42 (0.16)	**	0.50 (0.06)	**
Immunoglobulin M [$g.L^{-1}$]	0.17 (0.05)	**	0.10 (0.09)	**	0.16 (0.19)	*
Immunoglobulin G [$g.L^{-1}$]	4.12 (0.17)	*	4.54 (0.49)		4.43 (0.30)	**
Leukocrit [$10^9.L^{-1}$]	7.00 (2.33)		6.79 (1.38)		6.79 (1.72)	
Non-segmented neutrophils [$10^9.L^{-1}$]	3.85 (2.96)		16.69 (4.47)	*	14.47 (4.93)	
Neutrophils [$10^9.L^{-1}$]	66.31 (7.05)		70.46 (5.88)	*	36.07 (9.44)	
Monocytes [$10^9.L^{-1}$]	5.54 (2.56)		3.92 (2.16)	**	3.67 (1.44)	
Lymphocytes [$10^9.L^{-1}$]	22.31 (5.28)		8.46 (2.56)	*	42.80 (9.37)	
Eosinophiles [$10^9.L^{-1}$]	1.85 (2.41)		0.29 (0.45)		2.20 (2.31)	

Table 1. Changes in immunological characteristics of the expedition crew (means and standard deviatons – in brackets) evaluated before expedition, and two times during the Czech expedition to James Ross Island (Mendel station). The dates (20.1., and 10.2.) denote to January, 20th, and February 10th, 2015 respectively. Statistically significant differences are indicated by asterisks (* – $p < 0.05$; ** – $p < 0.01$).

Body Mass Index (BMI) after the stay was 25.43 (± 3.27) and did not show any statistically significant difference when compared to the BMI recorded before expedition. This is surprising and relates probably to food quantity and quality provided during the expedition. Earlier Antarctic expeditions of comparable short-term duration reported loss in body weight (Brotherhood et al. 1986). Overwintering crews, however, show increase in body weight and body fat as reported for Antarctica (*e.g.* Simpson and Mynard (2012) for the Rothera, UK station staff) and Arctic (Maciejczyk et al. 2017 for Polish polar station in Hornsund, Svalbard). However, even no change in body weight and BMI is reported from overwintering Antarctic crews (Bhatia and Pal 2013). Therefore, some variations BMI in Antarctic overwintering crews are considered to be season-dependent (Belkin and Karasik 1999, 2001; Simpson 2010) and attributed to the Antarctic residence impacts on energy dynamics and aerobic fitness attributed to raised basal metabolic rates and increased thermogenesis.

Previous studies on immunoglobulins showed that stress do alter the immunity. Changes in IgA are the first line of defence against stressing environmental factors because of IgA dominance in the mucosal immune system. It is well established that many of the stressors present in the Antarctic environment are known to affect the mucosal immune system (Gleeson et al. 2000, Gleeson and Pyne 2000, Mishra et al. 2011, 2014). Our data indicate a decrease in immunoglobuline A. This is well comparable to the evidence reported for Indian Antarctic crew (Mishra et al. 2011). In the study, immunoglobuline G levels decreased with stress, as documented for the Antarctic crew passing different levels of seasickness during ship journey from Cape Town to Indian Antarctic station Maitri.

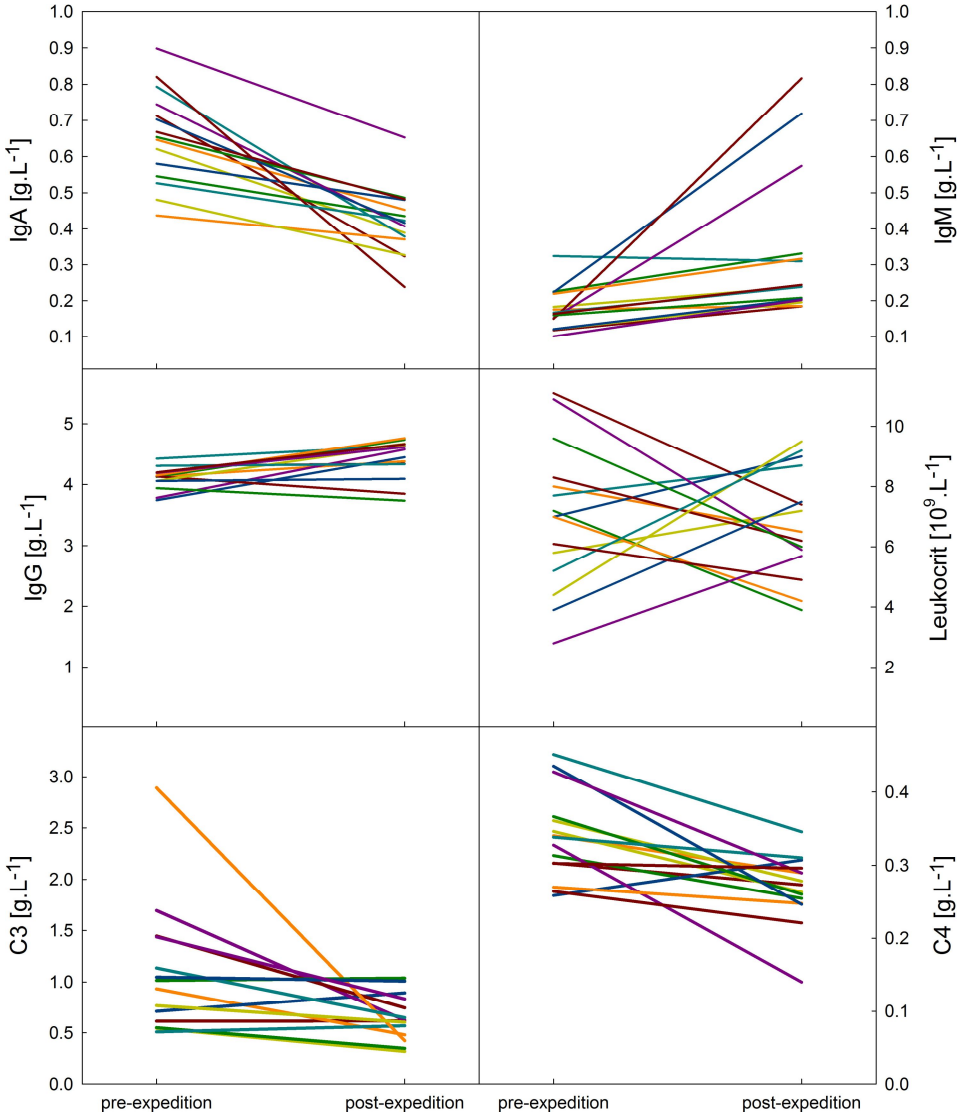

Fig. 1. Immunological parameters evaluated for 15 members of the austral summer season crew of the Mendel station (James Ross Island, Antarctica, before the expedition (1 at x-axis) and at the end of expedition (2 at x-axis).

Both parameters (IgA, IgG) showed linear relationship with severity of seasickness. Our data on IgA and IgG had the same trends with stress strength (*i.e.* duration of the Antarctic expedition) as those reported by Mishra et al. (2011). Moreover, our data on IgA were not in agreement with a pioneering study of Roberts-Thomson et al. (1985) reporting that individuals on the Antarctic ice-cap showed an increase in their IgA levels. Contrastingly, recent study of Bhushan et al. (2021) brings an evidence that both salivary and serum IgA increased as a result of Antarctic expedition of Indian crew (Bharati station and Larseman Hill camp).

Appart of serum IgA, several studies reported a significant change in salivary IgA as a consequences of intense physical exercise (*see* e.g. Nieman et al. 2002, Castilho et al. 2022). The relation, between serum/salivary IgA and coping with extreme Antarcic environment is, however, still poorly understood. The reason is that in Antarctic crews, the expedition members perform various activities which require different extensive physical activity. Therefore, the supression of imunology, typically demostrated by IgA decrease is still to be studied in respect to stress sources for particular crew members including physiological factors (Ursin et al. 1991).

References

BELKIN, V., KARASIK, D. (1999): Anthropometric characteristics of men in Antarctica. *International Journal of Circumpolar Health*, 58(3): 152-169.

BELKIN, V., KARASIK, D. (2001): The effect of season, occupation and repeated winterings on anthropologic and physiological characteristics in Russian antarctic staff. *International Journal of Circumpolar Health*, 60(1): 41-51.

BHATIA, A., PAL, R. (2013): Impact of Antarctica winters on vital parameters and anthropometric variables. *Travel Medicine and Infectious Disease*, 11(3): 170-177. doi: 10.1016/j.tmaid.2013.02.005

BHUSHAN, B., TANWAR, H., ESLAVATH, M., SINGH, S., KUMAR, B. and GANJU, L. (2021): Impact of the harsh Antarctic environment on mucosal immunity. *Antarctic Science*, 33(6): 624-632. doi: 10.1017/S0954102021000407

BROTHERHOOD, J. R., BUDD, G. M., REGNARD, J., HENDRIE, A. L., JEFFERY, S. E. and LINCOLN, G. J. (1986): The physical characteristics of the members during the International Biomedical Expedition to the Antarctic. *European Journal of Applied Physiology and Occupational Physiology*, 55(5): 517-523. doi: 10.1007/BF00421647

CASTILHO, T., GUIMARÃES, L. D., POVOA, H. C. C., ANTUNES, L. S. and ANTUNES, L. A. A. (2022): Influence of physical exercises on salivary immunoglobulin A (sIgA) concentration in athletes: A systematic review with meta-analysis. *Sport Sciences for Health*, 18: 621-639. doi: 10.1007/s11332-021-00870-4

FRANCIS, J. L., GLEESON, M., LUGG, D. J., CLANCY, R. L., AYTON, J. M., DONOVAN, K., MCCONNELL, C. A., TINGATE, T. R., THORPE, B. and WATSON, A. (2002): Trends in mucosal immunity in Antarctica during six Australian winter expeditions. *Immunology and Cell Biology*, 80: 382-390.

GLEESON, M., FRANCIS, J. L., LUGG, D. J., CLANCY, R. L., AYTON, J. M., REYNOLDS, J. A. and MCCONNELL, C. C. (2000): One year in Antarctica: Mucosal immunity at three Australian stations. *Immunology and Cell Biology*, 78: 616-622.

GLEESON, M., PYNE, D. B. (2000): Special feature for the Olympics: Effects of exercise on the immune system: exercise effects on mucosal immunity. *Immunology and Cell Biology*, 78: 536-544.

KAVAN, J., ONDRUCH, J., NÝVLT, D., HRBÁČEK, F., CARRIVICK, J. L. and LÁSKA, K. (2017): Seasonal hydrological and suspended sediment transport dynamics in proglacial streams, James Ross Island, Antarctica. *Geografiska Annaler: Series A, Physical Geography*, 99(1): 38-55, doi: 10.1080/04353676.2016.1257914

MACIEJCZYK, M., ARAŹNY, A. and OPYRCHAŁ, M. (2017): Changes in aerobic performance, body composition, and physical activity in polar explorers during a year-long stay at the polar station in the Arctic. *International Journal of Biometeorology*, 61: 669-675. doi: 10.1007/s00484-016-1244-6

MISHRA, K. P., YADAV, A. P., SHWETA, CHANDA, S., MAJUMDAR, D. and GANJU, L. (2011): Serum levels of immunoglobulins (IgG, IgA, IgM) in Antarctic summer expeditioners and their relationship with seasickness. *Cellular Immunology*, 271(1): 29-35. doi: 10.1016/j.cellimm.2011.05.018

MISHRA, K. P., YADAV, A. P., SHARMA, Y. K., GANJU, L. and SINGH, S. B. (2014): Effect of extreme conditions of Antarctica on human leukocyte antigen-G in Indian expeditioners. *The Indian Journal of Medical Research*, 140(4): 520-523.

MULLER, H. K., LUGG, D. J. and QUINN, D. (1995a): Cell mediated immunity in Antarctic wintering personnel; 1984-1992. *Immunology and Cell Biology*, 73(4): 316-320. doi: 10.1038/icb.1995.48

MULLER, H. K., LUGG, D. J., URSIN, H., QUINN, D. and DONOVAN, K. (1995b): Immune responses during an Antarctic summer. *Pathology*, 27(2): 186-190. doi: 10.1080/00313029500169852

NIEMAN, D. C., HENSON, D. A., FAGOAGA, O. R., UTTER, A. C. and VINCI, M. (2002): Change in salivary IgA following a competitive marathon race. *International Journal of Sports and Medicine*, 23: 69-75.

PROŠEK, P., BARTÁK, M., LÁSKA, K., SUCHÁNEK, A., HÁJEK, J. and KAPLER, P. (2013): Facilities of J. G. Mendel Antarctic station: Technical and technological solutions with a special respect to energy sources. *Czech Polar Reports*, 3(1): 38-57. doi: 10.5817/CPR2013-1-7

ROBERTS-THOMSON, P. J., LUGG, D., VALLVERDU, R. and BRADLEY, J. (1985): Assessment of immunological responsiveness in members of International Biomedical Expedition to the Antarctic 1980/81. *Journal of Clinical & Laboratory Immunology*, 17(3): 115-118.

RYKOVA, M. P., GERTSIK, Y. G., ANTROPOVA, E. N. and BURAVKOVA, L. B. (2006): Serum levels of immunoglobulins, allergen-specific IgE antibodies, and interleukin-4 in cosmonauts before and after short flights on the International Space Station. *Human Physiology*, 32: 457-460. doi: 10.1134/S0362119706040128

SHEARER, W. T., LUGG, D. J., ROSENBLATT, H. M., NICKOLLS, P. M., SHARP, R. M., REUBEN, J. M. and OCHS, H. D. (2001): Antibody responses to bacteriophage phi X-174 in human subjects exposed to the Antarctic winter-over model of spaceflight. *Journal of Allergy and Clinical Immunology*, 107(1): 160-164. doi: 10.1067/mai.2001.112269

SIMPSON, A. (2010): The effect of Antarctic residence on energy dynamics and aerobic fitness. *International Journal of Circumpolar Health*, 69: 220-235.

SIMPSON, A., MAYNARD, V. (2012): A longitudinal study of the effect of Antarctic residence on energy dynamics and aerobic fitness. *International Journal of Circumpolar Health*, 71: 17227. doi: 10.3402/ijch.v71i0.17227

STRATIS, D., TRUDEL, G., ROCHELEAU, L., PELCHAT, M. and LANEUVILLE, O. (2023): The transcriptome response of astronaut leukocytes to long missions aboard the International Space Station reveals immune modulation. *Frontiers in Immunology*, 14: 1171103. doi: 10.3389/fimmu.2023.1171103

TINGATE, T. R., LUGG, D. J., MULLER, H. K., STOWE, R. P. and PIERSON, D. L. (1997): Antarctic isolation: Immune and viral studies. *Immunology and Cell Biology*, 75: 275-283.

TURNER, J., ANDERSON, P., LACHLAN-COPE, T., COLWELL, S., PHILLIPS, T., KIRCHGAESSNER, A., MARSHALL, G. J., KING, J. C., BRACEGIRDLE, T., VAUGHAN, D. G., LAGUN, V. and ORR, A. (2009): Record low surface air temperature at Vostok station, Antarctica. *Journal of Geophysical Research-Atmospheres*, 114: D24102. doi: 10.1029/2009JD012104

URSIN, H., BERGAN, T., COLLET, J., ENDRESEN, I. M., LUGG, D. J., MAKI, P., MATRE, R., MOLVÆR, O., MULLER, H. K., OLFF, M., PETTERSEN, R., SANDAL, G. M., VÆRNES, R. and WARNCKE, M. (1991): Psychobiological studies of individuals in small, isolated groups in the Antarctic and in space analogues. *Environment and Behavior*, 23(6): 766-781.

WILLIAMS, D. L., CLIMIE, A., MULLER, H. K. and LUGG, D. J. (1986): Cell-mediated-immunity in healthy-adults in Antarctica and the sub-antarctic. *Journal of Clinical & Laboratory Immunology*, 20: 43-49.

YADAV, A. P., MISHRA, K. P., GANJU, L. and SINGH, S. B. (2012): Wintering in Antarctica: Impact on Immune Response of Indian Expeditioners. *Neuroimmunomodulation*, 19: 327-333.

ŽÁKOVSKÁ, A., ZEZULOVÁ, O. and BRAT, K. (2015): Changes in immunological and physiological parameters in urine during Antarctic Scientific Expedition. *Czech Polar Reports*, 5(1): 69-74. doi: 10.5817/CPR2015-1-7

ŽÁKOVSKÁ, A., ZEZULOVÁ, O. (2016): Some of the metabolic changes in expedition members caused by diet and activities performed during a stay at the Czech Antarctic based. *Czech Polar Reports*, 6(1): 13-20. doi: 10.5817/CPR2016-1-2