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REVIEW ARTICLE

Back to the basics of polar expeditions: personality hardiness, fear, and nutrition in polar environments

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Abstract
The present paper aims at presenting an overview of findings relating personality hardiness to adaptation to polar environments. Several studies from the Operational Psychology Research group at the University of Bergen have depicted individual characteristics of high hardy subjects involved in stressful activities in polar environments. These high hardy subjects have superior coping skills, are less influenced by environmental stress, show increased motivation during endurance activities, and have a more adaptive biological stress response. It could be assumed that explorers undertaking solo expeditions in polar environments would represent extremely hardy people. Thus, in addition to previously reported studies on hardiness in polar environment, the results from two previously published papers are presented and re-interpreted. The studies provided a rare opportunity to separate the effects of extreme physiological and emotional strain (mainly fear) and present the trajectory of relevant biomarkers of fear, stress, appetite, and nutritional status during a 90-day expedition across Antarctica. The studies expanded on previous knowledge by showing extreme variations in biomarkers during the expedition and suggested that extreme fear has the highest impact on indicators of stress, stress regulation, appetite, and nutritional status. This, together with the recovery effects found on nutrition status after a daily energy uptake of 5–6000 kcal, expands on previous knowledge about adaptation in polar environments.

Keywords Polar environment · Hardiness · Biomarkers · Adaptation · Fear · Appetite · Nutrition

Introduction

Both the Arctic and Antarctica are historically inhospitable and uninhabited environments. Polar explorers and later winter-overs have been described as possessing—personality characteristics that allow them to endure the hardship of the polar environment and adaptation to the challenges they are exposed to. Several authors have categorized the challenges involved in adaptation to polar environments as social, emotional, occupational, and physical stressors (Nicolas et al. 2021). This includes harsh climate, physical load, restricted access to nutrition, and emotional aspect of a complex psycho-social situation. In the most extreme, fear of the unknown, as well as fear of a fatal outcome could be prominent.,

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Why study polar expeditions?

Palinkas and Suedfeld (2008) categorize polar expeditions in three distinct categories. Expeditions includes long-haul ski-marches, scientific summer camps and the third is winter-overs at a polar research station. Common factors for these expeditions are a variety of exposures to cold, danger, deprivation, and physical demands.

According to Schweitzer (2017), human activities have intensified in polar areas, and people are increasingly making the region their home. In addition, polar expeditions could generate specific knowledge on hard-to-observe phenomena by simulating human adaptation in extreme conditions. For instance, NASA is planning for a variety of manned deep space explorations (NASA 2014). The risks identified in these missions, related to both interplanetary flight and surface activity on planets (Kozlovskaya et al. 2010), are comparable to the exposures experienced by polar explorers. This includes enduring isolation, hard physical activity in extreme temperatures, emotional challenges, fear of injuries and death, and limited variation in nutrition (Bartone et al. 2019). Polar expeditions have been described as "earth-bound" analogs to deep-space explorations (Strewe, et al. 2019; Suedfeld & Weiss 2000), and in order to prepare for these missions experience from comparable situations may serve as an important reference point (Johnsen et al. 2021). It could be argued that these positions point to a need for generating more knowledge on adaptation to extreme cold environments in general. Thus, knowledge of factors and mechanisms involved in adaptation to polar environment could mitigate the reported challenges.

Adaptation to extreme environments could be viewed as both the process and the outcome of a polar expeditions. In the present study we view adaptation in line with Nicolas et al. (2021) which understand the process of adaptation as a constant dynamic process of adjustment to the environment. As stated by Nicolas and coworkers (2021) this includes all responses to physical, social and psychological challenges.

There are several approaches to mapping adaptation to polar environment. We have chosen two approaches in this overview. One includes the study of soldiers on demanding military winter exercises in polar environments. Such an approach involves the common challenges reported by Palinkas and Suedfeld (2008). The challenges of exposures to cold is present since the exercises are performed above or close to the arctic circle during winter conditions. There is always an element of danger in military exercises by handling of military equipment during a state of exhaustion. Sleep and food deprivation are almost a standard element during this type of exercises as well as hard physical activity including strenuous ski-marches.

The other approach chosen, was to investigate biomarkers of adaptation during a solo expedition across Antarctica. Due to logistical constraints, most studies involving biomarkers in polar explorers tracking long distances, have utilized a pre-post design. These types of designs have some limitations regarding causal inferences of temporal trends. As a consequence, there is a need for longitudinal studies especially for long-haul explorers. This also includes, in addition to the interplay between environmental challenges and physiological responses, the interaction between emotional challenges and physiological responses.

The present paper aims at presenting an overview of findings relating personality hardiness to adaptation to polar environments. Secondly, since adaptation involves a dynamic interplay between the environment and emotional and physiological responses, trajectories of relevant biomarkers of adaptation are outlined. It is reasonable to believe that the studies presented involves increased metabolism due to cold temperature and hard physical activity. Thus, longitudinal data of nutritional status during a solo expedition across Antarctica will be described, and mechanisms involved in signaling appetite and malnutrition be proposed.

Personality of polar explorers

Based on the activity of polar explorers, it is reasonable to believe that individual characteristics are fundamental in motivating for their venture into these extreme environments. The study of individual characteristics possessed by polar explorers is often based on case studies analyzing text entered in their diaries. In a solo expedition to the South Pole, personality descriptors like conscientious, achievement-oriented, practical, and an ability to self-regulate activation were extracted (Suedfeld et al. 2017), while other studies have emphasized winter-over residents as being high in stress resistance (Weiss et al. 2000; Rui et al. 2016). Resilience seems to be a common characteristic based on the studies of personality factors of explorers and winter-over residents. Resilience is characterized by a positive adaptation in spite of adverse life experiences, including situations involving severe risk factors (Friborg et al. 2009). Personality hardiness has been viewed as a specific form within the resilience perspective and is suggested to explain individual differences in adaptation to hazardous environments (Bartone and Hystad 2010; Bonanno 2004; Johnsen et al. 2004).

Personality hardiness

Hardiness is regarded as a broad individual personality style and as a generalized mode of functioning (Bartone 2006) encompassing the three inter-related dispositions or subdimensions of commitment, control, and challenge. The commitment disposition relates to a tendency to take a genuine involvement in one's surroundings and tasks at hand and to view them as meaningful. Individuals high on this disposition will be attentive to the task and their surroundings, show task-oriented behavior, be supportive towards team members, and show an ability to motivate self and others. The control subdimension encompasses the tendencies to act and believe that one's own effort influences the events that occur in one's life and surroundings. Individuals high on this disposition are characterized by elevated self-efficacy and self-regulation when confronted with stressful situations. The challenge disposition incorporates the belief that change is normal and that challenges involve opportunities for learning and personal growth. Subjects high on this dimension will be perceived as pro-active and willing to approach hardship rather than avoid it. Thus, hardiness is thought of as the source for the motivation and courage needed to change stressful circumstances into opportunities for personal growth. In addition to the three dimensions, hardiness reflects the ability to combine an orientation towards the future with the competence of learning from the past (Bartone and Hystad 2010).

To our knowledge there are relatively few studies of hardiness and adaptation to polar environments. An exception is Weiss and coworkers (2000) who reported hardiness to correlate with measures of coping ability in Antarctic expeditions. The study consisted of three samples of winter-over residents of a Japanese research station in Antarctica, and an interesting and consistent finding was a reduction of hardiness from pre to post expedition. This effect was most salient for the challenge sub-scale. The results were interpreted as an indication of a greater appreciation of the threat induced by the extreme winter conditions, elucidating a more conceivable perception of control over events and outcomes. According to Weiss and coworkers (2000), these changes convey a "reasonable and realistic understanding of the kind of coping that is advisable in this kind of extreme and unusual environment".

In a series of studies from the Operational Psychology Research Group at the University of Bergen, hardiness has been related to adaptation and performance in Arctic environments. Johnsen and colleagues (2013) showed that hardiness predicted successful completion of a rigorous 250 km ski march over 9 days in Arctic winter conditions (i.e. north of the Arctic Circle). The sample studied included drafted military personnel aged between 18 and 23 years participating in the final portion of a selection program for rangers along the Russian–Norwegian border. Longitudinal data based on a daily survey showed that the high hardy group showed higher evaluation of positive appraisal of the march compared to the low hardy group. Furthermore, the high commitment group reported the highest levels of positive daily coping and evaluated their performance more positively. This group also showed increasingly positive self-evaluations as the exercise went on. All self-evaluations were made by using a 10 cm visual analog scale. The Johnsen et al. (2013) study reported that hardiness predicted successful completion of the ski march even after nutritional factors, physical fitness, and the personality dimension of sensation seeking were controlled for., The disposition of commitment was the most significant predictor of ski march success, again controlling for nutrition, physical fitness, and sensation seeking. Although, the ski-march lasted for only nine days it could be hypothesized that hardiness and especially the commitment dimension are related to adaptation to an arctic endurance task requiring sustained effort. Johnsen et al. (2013) suggested that the mechanism in which hardiness exerts its influence on adaptation and performance is by enhancing active coping skills and self-efficacy. These results were supported using a similar but larger sample, showing an increase in motivation as well as coping over the course of the ski-march for participants high on both commitment and control (Sandvik et al. 2010). The relation between hardiness and coping skills are supported by several studies indicating a mediating effect of coping skills between hardiness and health variables. This has been found in Norwegian military samples deployed to international operations (Thomassen et al. 2018) and US and Norwegian military samples deployed to war zones (Bartone et al. 2016). The mediating effect of coping style between hardiness and symptoms of mental distress has also been reported to be present for both male and female subjects in a civilian sample (Thomassen et al. 2021).

Traditionally, studies relating hardiness to performance and health have treated the construct as a linear disposition. Individual differences in hardiness have thus included a range from low to high hardy persons. Johnsen and coworkers (2014) reported individual differences characterized by profiles of the specific dispositions in the hardiness construct. Based on cluster analyses of a military sample, four profiles were defined. The High Hardy cluster showed high scores on all three facets of hardiness, while the Low Hardy cluster showed low scores on all facets. The Sensation Seeking cluster was characterized by low control and commitment, but high on the challenge disposition. The Rigid Control cluster was characterized by low scores on challenge but medium to high scores on control and commitment. These clusters share commonalities with studies on biomarkers of hardiness. Bartone and colleagues (2011) identified a subgroup of hardiness characterized by an unhealthy lipid pattern of elevated triglycerides combined with high levels of low-density lipoprotein. This subgroup revealed a hardiness profile where challenge scores were lower compared to commitment and control scores.

Hardiness and biomarkers of adaptation in polar environments

The findings of hardiness profiles (Johnsen et al. 2014; Bartone et al. 2011) have motivated further studies on biomarkers of adaptation during extreme hardship. The Norwegian Armed Forces specialize in conflict in arctic environments, and officer schools have mandatory high-stress training under these conditions. By measuring relevant biomarkers of adaptation reflecting stress and stress regulation, studies have indicated that elevated levels of stress hormones like glucocorticoids and catecholamines released by the adrenal gland suppress the production of pro-inflammatory cytokines and stimulate the production of anti-inflammatory cytokines (Elenkov and Chrousos 2002; Padget and Glaser 2003; Padgett et al. 1998). The secretion of stress hormones is regulated by the hypothalamus through the hypothalamic–pituitary–adrenal axis, and studies have linked potential effective behavioral stress regulation to higher levels of neuropeptide-Y (NY) (Morgan et al. 2002; Yehuda et al. 2006). It has been suggested that NY exerts its effect by reducing the release of stress hormones, and it interacts with the HPA-axis by counteracting the biological actions of corticotropin releasing hormone.

How to measure biomarkers in arctic conditions? Biomarkers are often filtered from blood samples and harvesting blood in the field confronts researchers with logistical obstacles. The need for support from medical professionals in order to penetrate the skin, the requirement for keeping samples cold until analyses, and transport issues like storage, weight, and size of the samples and their containers are examples of difficulties encountered in field studies. Over the last decades an increasingly popular method for field studies of "wet" parameters is the "dried bloodspot" (DBS) method. This could be used as an alternative to analyses of saliva samples since blood is proposed as the best body fluid in order analyze systemic processes (Williamson et al. 2012).

The DBS method involves drawing a drop of blood onto a piece of filter paper. The blood drop is then dried, marked, and stored. DBSs harvested in Antarctica have successfully been analyzed 9 months after an Antarctic expedition (Johnsen et al. 2020) using chip-based immunoaffinity capillary electrophoresis (CB-ICE; Phillips 2004; Mihalopoulos et al. 2011). The method showed high concurrent validity when compared to psychological states described in the diary of the explorer (Johnsen et al. 2020). The DBS method overcomes many of the shortcomings of traditional sampling because the method allows for self-administration of blood sampling, it is light weight, and, if properly stored, it is not mechanically influenced.

Personality hardiness and biomarkers of stress and stress regulation in polar environments

In a study from our research group, the association between hardiness and biomarkers of stress and stress-regulation was investigated in a sample of naval officer cadets conducting a highly stressful winter exercise (Sandvik et al. 2013). The exercise lasted seven days and was designed with a dramatic increase in physical and mental stress on day five. Hardiness was measured two days before the exercise, and blood was harvested using the DBS method on days five and seven. The subjects were separated into a consistent high hardy group ("hardiness balanced") and a "hardiness unbalanced" group (Bartone et al. 2011). The main characteristics of the unbalanced group were lower scores on the challenge compared to the control disposition, referred to by Johnsen et al. (2014) as rigid control.

By comparing the data from day five and day seven, the results revealed an increase in stress reactivity. However, this occurred only for the hardiness "unbalanced" subjects showing suppressed pro-inflammatory cytokines (interleukin (IL)-12) and increased levels of anti-inflammatory cytokines (IL-4 and IL-10) during the high stress period. The "balanced group" showed a fairly stable level of IL-12 and a decrease in anti-inflammatory cytokine levels (IL-4) during the high stress conditions. Looking at biomarkers of stress regulation, the "unbalanced" group showed lower ability to regulate their behavioral stress responses as indicated by a decrease in NY levels from day five to seven. The hardy "balanced" group showed the opposite effect by increasing their levels of NY during the stressful part of the exercise.

Sandvik and colleagues (2013) interpreted the result as the hardy "balanced group" showing more stress-resilience and more adaptive and healthy responses to stress in contrast to the "unbalanced group" when faced with stressful conditions that involve hard physical activity, threatening, surprising, and unexpected developments. Furthermore, the authors advocated that the study highlighted the immune system as a biological system through which hardiness can have beneficial stress-buffering effects and thus contributes to explaining the biophysical processes underlying the hardiness concept. An alternative interpretation could be based on the taxonomy of Johnsen and colleagues (2014). As stated, the "unbalanced group" shares the core characteristics with the rigid control profile (Johnsen et al. 2014). This implies a need for predictability, and these persons show a cognitive style with a preference for known situations. This is based on the profile's high scores on commitment and control dispositions indicating a preference for situations in which they feel they can control the outcome and can remain dedicated to the tasks and the social world around them. This, together with the low challenge score, where change is perceived with negative anticipation and low capacity for learning from the situation, could lead to non-adaptive stress responses and a lower ability to regulate one's own stress behavior.

Biomarkers of a polar explorer

It could be inferred from the studies outlined above that polar explorers show high degrees of the dispositions of commitment, control, and challenge (e.g. they are hardy persons). This section is based on two longitudinal studies (Johnsen et al. 2020; 2021) investigating a polar explorer conducting a 93-day unsupported solo crossing of Antarctica. At the time, this was considered the longest ski-march ever conducted, and the explorer travelled 4804 km in 93 days (from November 4th, 2005, to February 8th, 2006; see Gjeldnes 2006 for a detailed description of the expedition). This ski march was 1000 km longer and was completed 10 days faster compared to the previous record. The crossing started at the Russian NOVO station in Queen

Mauds Land, continued 2200 km to the South Pole, and then an additional 2600 km to the Italian Zucchelli research station located at Terra Nova Bay by the Ross Sea. The ski march varied in altitude from sea level to 3300 m. The specific route into the South Pole and to the final goal, Terra Nova Bay, had never previously been traveled.

Biological markers and adaptation during a solo expedition in Antarctica

In a study primarily to test the concurrent validity of the DBS method in polar environments, Johnsen et al. (2020) analyzed the explorer's diary searching for words and phrases related to stress, strain, and statements describing emotions. Six distinct phases were identified based on their core characteristics. By separating the expedition into phases, one can compare the relationship between biological markers and the characteristics of each phase. The two most important phases found were ascending from sea level to the polar plateau and navigating the Priestly glacier. The ascending phase was characterized by extreme physical strain because the explorer had to haul 180 kg of supplies from sea level to the plateau at 3300 m. The main factor in the crossing of the Priestly glacier was psychological stress, pertaining to fear caused by the threat of extreme winds and crevasses. Examples from the diary are:" I have never before felt the fear of dying as intensely as now. I´m in the middle of the glacier. Alone. I can´t afford to make a single mistake" and "I have felt the fear of death strongly for many days now" (see also Gjeldnes 2006, p. 105 for more descriptions).

The glacier, 170 km long, has never been navigated by humans, neither before nor after the expedition. The threat exposed by the glacier is evident in the reaction from the researchers at the Italian Zuchelli station, where the inhabitants initially refused to believe that it had been travelled.

Four other phases were defined (See Fig. 1) based on the diary. The baseline was marked by psychological stress related to anticipatory processes and crossing of the plateau was described as low-intensity sustained physical strain due to the use of kites as well as the impact of extremely low temperatures. The descent towards the Priestly glacier was found to contain some fear caused by occasional crevasses, and the recovery phase was described in terms of light psychological stress related to the absence of significant others and relief.

The DBSs were planned to be harvested twice a week and before consumption of dinner. However, the regularity of sampling varied somewhat due to situational factors. The DBSs were analyzed using the same method as described above.

Biomarkers of stress and stress-regulation The glucocorticoid cortisol is regarded as a main stress hormone and is thought of as involved in the human fight-flight response and in the regulation of metabolic processes. Cortisol levels were extracted from the DBSs sampled during the expedition (Johnsen et al. 2020). Figure 2 shows the mean levels of cortisol separated according to the different phases identified in the analyses of the explorer's diary. The results from Johnsen et al. (2020) study showed a 172% increase in cortisol level from baseline during extreme physical strain (the ascent phase) followed by a reduction to baseline levels while crossing the plateau. However, the greatest increase in cortisol levels was found during intense psychological stress (i.e. fear). Crossing the Priestly glacier represented a 251% increase from baseline level (see Fig. 2 upper left panel.) Parallel findings were found for the

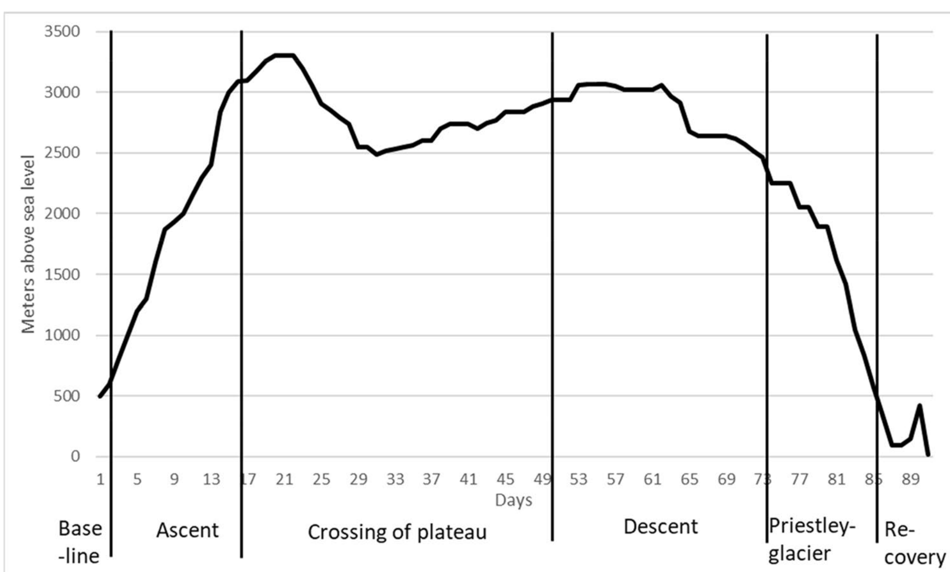

Fig. 1 Shows the altitude (meters above sea level) along the phases distilled from the analysis of the explorer's diary (reproduced with permission from Necesse)

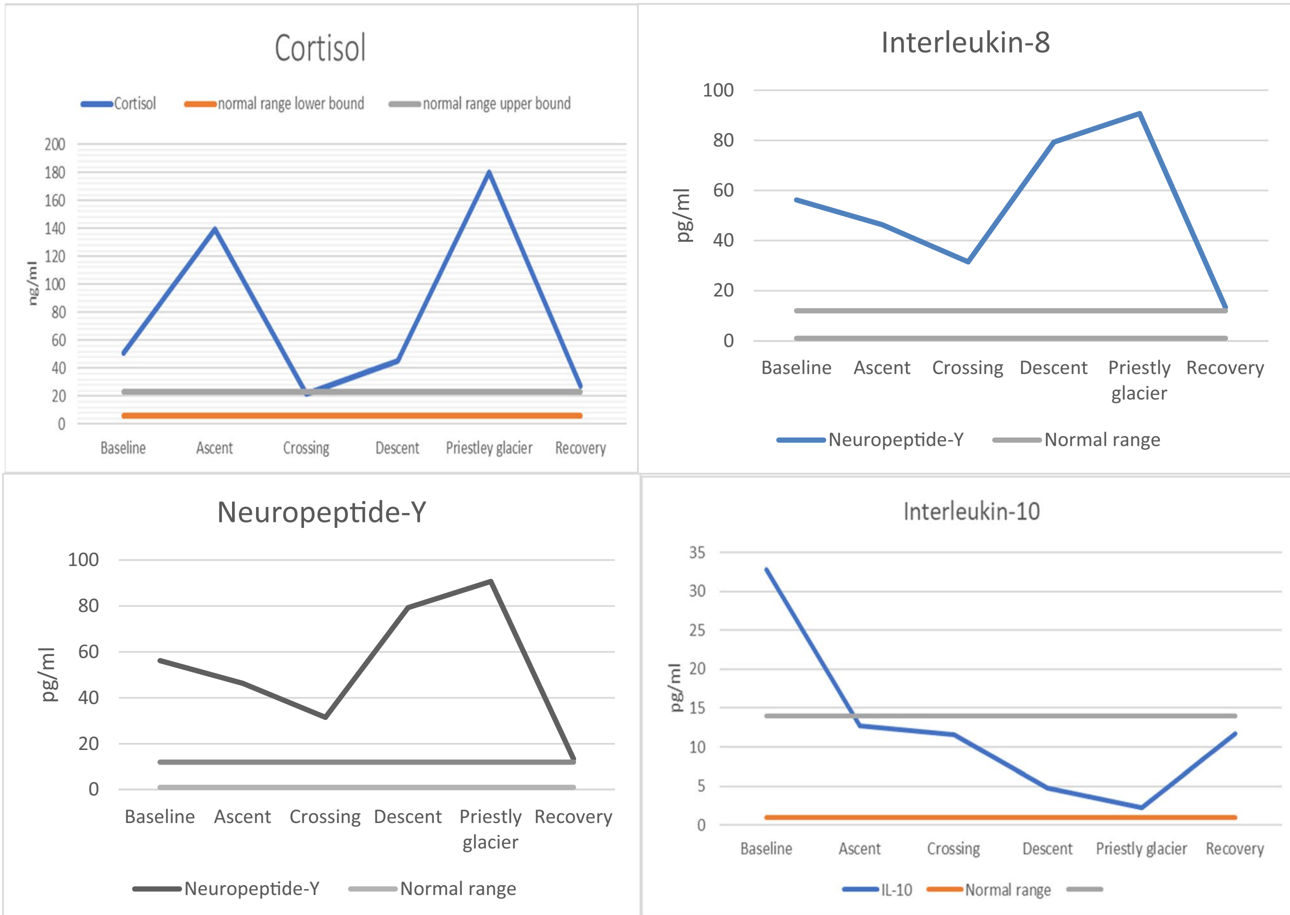

Fig. 2 Presents the trajectory of cortisol (upper left panel), neuropeptide-Y (lower left panel), interleukin-8 (upper right panel), and interleukin-10 (lower right pane). The data are separated according to the different phases of the expedition (reproduced with permission from Necesse)

corticosteroid epinephrin with the highest peaks of single measures during physical strain and the period characterized by fear. The peak measurement in the ascent phase was close to three times the baseline value, and the phase characterized by extreme fear (Priestly glacier) peaked at five times the baseline value.

NY was used as a marker of adaptive stress regulation and showed a 17% decrease during extreme physical strain. The lowest level of NY was found during the crossing of the plateau with a 44% decrease from baseline level. Extreme fear showed the highest recording of NY with an increase of 61% compared to baseline. The descent, characterized by a fair amount of psychological stress (mainly fear of crevasses), also showed an increase (41%).

Biomarkers of inflammatory processes Physical activity is known to modulate inflammatory processes. Increased activity within the normal range has a positive effect on the immune system (Phillips et al. 2017) by reducing serum levels of pro-inflammatory interleukins and increasing anti-inflammatory interleukins (Díaz et al. 2018). In a study of ski athletes involved in high-intensity physical training and strong psychological stress conducted under adverse environmental conditions, functional and biochemical changes in the immune system were seen that were equivalent to those seen during infection (Evstratova et al. 2016). The authors claimed that long-term regular exercise can lead to chronic systemic inflammation. However, a systematic review (Kasapis and Thompson 2005) concluded that homeostatic regulation of the immune system takes place during physical exercise, including a short-term inflammatory response followed by a long-term anti-inflammatory response.

The study by Johnsen et al. (2020) showed that all measurements of IL-8 (pro-inflammatory) were above the normal range with an increase from baseline of 70% during extreme physical activity (the ascent phase) and an increase of 400% during extreme fear (crossing the Priestly glacier; See Fig. 2 upper right panel). The data from analyses of the anti-inflammatory IL-10 mirrored the responses from IL-8. Compared to baseline level, a reduction of 79% was found during extreme physical activity (the ascent phase) and a reduction of 93% during extreme fear (crossing the Priestly glacier). In addition, a 37% reduction was found during the descent.

Markers of reward Psychological changes take place as important events occur, which again have physiological implications. One biomarker that has been related to positive emotions, and especially the notion of reward, is the hormone β-endorphin. Because β-endorphin is an endogenous opioid, increased levels of β-endorphin are associated with feelings of reward and reduced feelings of pain. Thus, the hormone could be released both from positive experience creating a feeling of reward and the involvement in negative actions resulting in pain sensations.

The trajectory of β-endorphin across the expedition is outlined in Fig. 3. The study by Johnsen et al. (2020) revealed above-normal levels of β-endorphin at baseline and during the crossing and recovery phases. The β-endorphin level peaked during the crossing of the plateau, with an increase of 181% compared to the baseline level.

Appetite and nutritional status during the solo expedition

Nutritional aspects in polar environments are a reoccurring theme, and especially for solo expeditions. Unsupported expeditions have no resupplies planned, which increases the risk of malnutrition and consequently the risk of fatal outcome. This, together with lack of social and manually support, elevates the psychological challenges by increasing worry and fear. In a study from our research group (Johnsen et al. 2021), the DBSs sampled during the solo crossing of Antarctica (Gjeldnes 2006) were reanalyzed for markers of

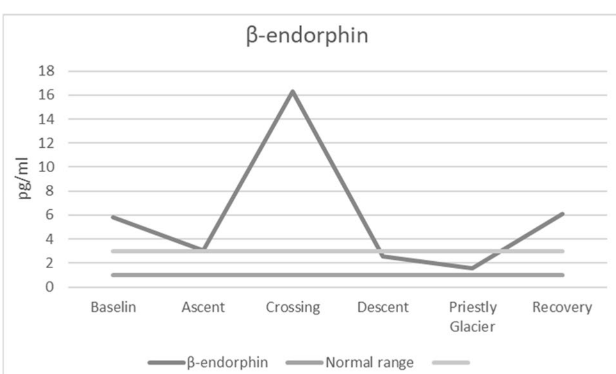

Fig. 3 Presents the trajectory of β-endorphin separated according to the different phases of the expedition (reproduced with permission from Necesse)

appetite and nutritional status. The daily calorie intake was planned to be 5100 kilocalories (kcal) during the first part of the expedition, and this was planned to be increased to 5900 kcal during the last 48 days. Figure 4 gives an outline of the study by Johnsen and colleagues (2021).

As can be seen in Fig. 4, the background for the Johnsen and colleagues (2021) study, was the well-known relationship between physical activity and metabolic processes (Benedini et al. 2017) as well as a supposed link between cold temperature, psychological strain and metabolism. The latter assumption was based on studies indicating elevated metabolic rates in populations in Arctic environments compared to inhabitants of temperate and tropical climates (Leonard et al. 2002). Furthermore, psychological strain as a result of cognitive tasks (Bruckmaier et al. 2020) and adverse early life experience has also been suggested to be related to metabolism (Joung et al. 2014).

Due to limited access to food, preventing malnutrition and appetite regulation could be considered a salient adaptation process to environmental challenges during polar solo expeditions. Increased metabolism can cause an energy imbalance that is mitigated by increased calorie uptake. A precursor for feeding behavior is often an increased feeling of hunger, which is suggested to be regulated by the hormones leptin and adiponectin. The circulating level of leptin, which is released by adipose tissue, is thought of as regulating energy balance, and increased levels of leptin is reported to inhibit feelings of hunger (Dundar, et al. 2019). Adiponectin, which is also released by adipose tissue, is reported to be an appetite-stimulating hormone, and increased levels result in reduced glucose output from the liver. As can be seen in Fig. 4, the need for energy while in a situation with restricted access to energy could result in a detrimental nutritional status. One way to monitor nutritional status is by means of the proteins globulin and albumin, and a reduced albumin/globulin ratio is considered an index of malnutrition (Gundog and Basaran 2019).

Subjective feelings of appetite and hunger as a result of physiological changes in circulatory levels of hormones and proteins indicate ascending pathways from the body to the mind. IL-6, which is released by muscle contractions, is suggested to be a mechanism for the cross-talk between muscle and adipose tissue, between muscles and the liver, and between muscles and the brain (Pedersen 2012; Pelacio-Gonzales et al. 2015). The phases distilled from the explorer's diary provided the opportunity to compare appetite regulation during extreme physical versus emotional stress (i.e. fear) as well as to monitor nutritional status across the expedition.

Trajectory of appetite-regulating hormones Both leptin and adiponectin were found to be within the normal range (See Table 1) with the exception of leptin levels during the crossing of the Priestly glacier, and the extreme fear

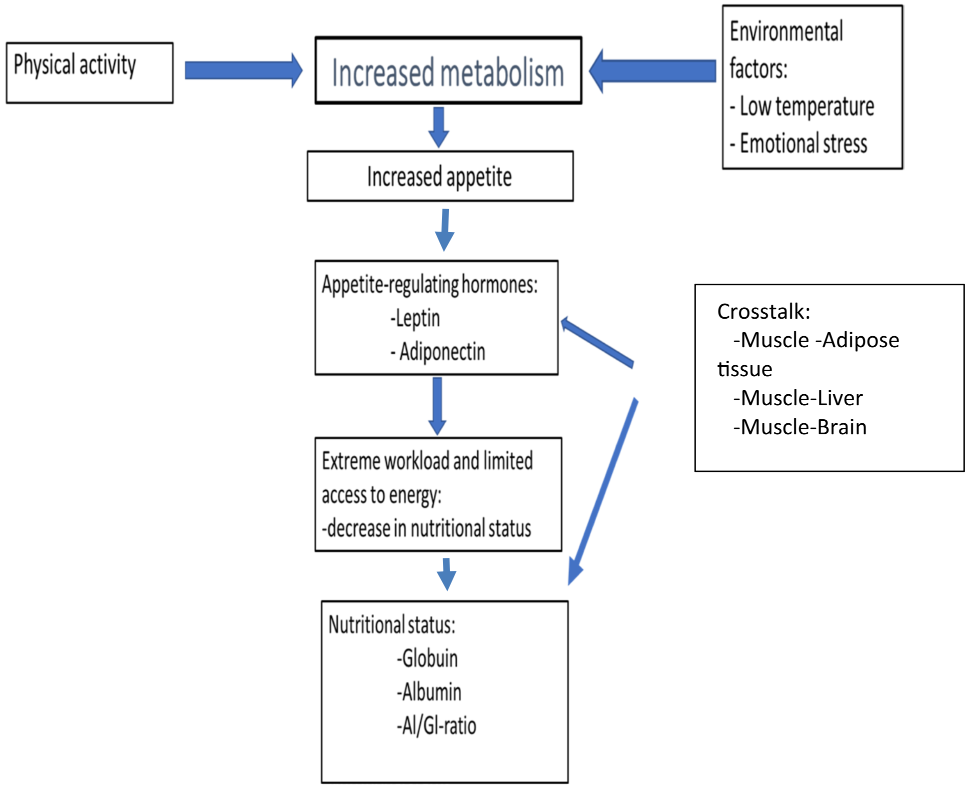

Fig. 4 Presents a schematic outline of the study by Johnsen et al. (2021)

Table 1 Presents the mean scores of appetite regulating hormones (Leptin and Adiponectin) measured in micrograms pr. milliliter (µg/mL) and nutritional status (albumin/Globulin) measured in milligrams pr milliliter (mg/Ml). The table also presents measures of initerleukin -6 (Il-6) measured as picogram pr milliliter (pg/Ml). The data are separated for the six phases of the expedition (Johnsen et al. 2021)

Variable	Baseline	Ascent	Crossing	Descent	Priestly glacier	Recovery	Normal range
Leptin (µg/mL)	16.5	6.62	13.71	18.9	3.8	15.23	4.7–23.7
Adiponectin (µg/mL)	14.1	6.34	15.01	18.1	2.75	18.1	2–30
Al/Gl-ratio (mg/Ml)	1.8	1.14	1.91	2.01	0.8	1.9	1.1–2.5
Il-6 (pg/Ml)	65.9	144	31.13	292.6	286.25	13	1–14

experienced in this phase could be the cause of the observed leptin levels below the lower bound of the normal range. When comparing the extracted hormones to baseline levels, the results showed a marked reduction (60%) in leptin during extreme physical activity (Ascent), and the lowest level (a 77% decrease) was found during extreme fear (Priestly glacier). Parallel findings were found for adiponectin, with a 55% decrease during extreme physical activity (Ascent) and the lowest level (an 81% decrease) during extreme fear (Priestly glacier). Both measures showed recovery effects in the phase succeeding the marked decrease in appetite-regulating hormone levels.

Trajectory of nutritional status Results from the analyses of the albumin /globulin ratio showed the same pattern as for appetite-regulating hormones (see table one). All measurements were within the normal range except for the crossing of the Priestly glacier (92% reduction from baseline) where the ratio was below the lower bounds of the normal range. During the ascent towards the polar plateau, a reduction of 17% was found. Also, when testing nutritional status, recovery effects were found in the phase succeeding the marked decrease.

Trajectory of IL-6 The results for IL-6 showed measurements above the normal range for all phases except recovery. During recovery, the IL-6 level bordered the upper range (see table one). When comparing the Il-6 levels in the different phases of the expedition to the baseline level, an increase of 119% was found during the ascent phase. The descent and crossing of the glacier showed an increase of 344% and 343%, respectively.

General discussion

A common perception of the personality characteristics of polar explorers as well as winter-over residents is their ability to endure extreme hardships. This notion is supported by studies indicating personality characteristics such as goal-orientation, emotional stability, and team orientation (Leon et al. 1989; Rui, et al. 2016). These indicate a hardy personality style that is characterized by a general perception of hardship as something to approach (Challenge disposition), an orientation towards other team members and the goal of the activities (Commitment disposition), and the belief that one's own investment in activities determines the final outcome in reaching the goal (Control disposition). Although hardiness is correlated with coping behavior (Thomassen et al. 2021) and the traditional Big-Five dimensions of personality, studies have confirmed the independence of the construct (Eschleman et al. 2010; Johnsen et al. 2014). It could therefore be argued that personality hardiness constitutes a significant descriptor of polar explorers' personalities. This is further supported by empirical studies where hardiness has been found to successfully predict military selection in an Arctic environment involving endurance activity using skis (Johnsen et al. 2013) and to predict adaptive biological stress regulation during rigorous military winter training (Sandvik et al. 2013).

In general, knowledge of biological adaptation during polar expeditions has been derived from inferences based on the difference between measurements taken before and immediately after the completion of the mission. As an example, Kern et al. (2019) concluded that the impact of stress on explorers was moderate because the stress hormone cortisol only showed a moderate increase from pre to post expedition. A study from our group confirmed the moderate increase in cortisol level (Johnsen et al. 2020). More importantly, extensive variations in cortisol levels were found during the expedition, showing a variation from baseline up to 270% during extreme fear and up to 172% during extreme physical stress. The trajectory of cortisol levels and its relation to physical demands and subjective experience of emotions could be an example of the dynamic interplay on a physiological level during the adaptation process.

The study by Johnsen et al. (2020) further expands on previous knowledge by suggesting that the experience of fear has the highest impact on biological markers of stress and stress regulation when the latter was measured as production of NY. The study lends support to Elenkov and Chrousos (2002) by showing increased cortisol levels, suppression of pro-inflammatory interleukins, and an increase in anti-inflammatory interleukins and adds to previous knowledge by showing that this effect is more salient during the negative emotional experience of fear. Furthermore, this phenomenon was present even with extreme elevation of the stress-regulating marker NY. Our interpretation is that NY is not able to totally inhibit the release of cortisol due to the extreme stress of the situation. However, NY might be thought of as capping the peak of the cortisol levels, thus representing a form of adaptive stress regulation.

Several studies on biomarkers in polar explorers have looked at indicators of stress and strain. The study by Johnsen et al. (2020) also reported on biomarkers of positive cognitive processes. β-endorphin, as a marker of reward, showed a major peak during the crossing of the polar plateau. This could be caused by the rewarding feeling of progress due to the daily completion of long distances by kite. However, some caution should be taken because β -endorphin is also a marker of pain regulation, and this phase of the expedition also included pain caused by frostbite, especially in the toes.

The second publication based on the Antarctic expedition (Johnsen et al. 2021) focused on adaptive processes of appetite and nutritional status. Physical exercise in cold environments have shown a decrease in leptin and an increase in adiponectin levels as a precursor of sensation of hunger and feeding behavior (Becic et al. 2018). The results described by Johnsen and coworkers (2021) did not support this finding, and both parameters showed parallel trajectories. The Johnsen and colleagues (2021) study differed from the Becic et al. (2018) study by investigating the effect of exposure to extreme cold temperature. It has been suggested that in cold environments, when both hormones show parallel expressions, the effects of leptin would dominate (Laursen et al. 2017). This can be viewed from an evolutionary perspective. Leptin signals to the thalamus that energy needs are not being met, but adiponectin does not signal a need for increased energy uptake. Maximal intensity of behavior is most likely performed because of the utmost importance for survival of the organism. During extreme experience of fear and during extreme physical activity, often in combination as in avoidance behavior, feeding has to be postponed until the threat is removed or the goal of the behavior is achieved. Thus, the sensation of hunger is therefore postponed.

The study by Johnsen et al. (2021) also proposed that IL-6 levels are a result of extensive muscular work/contraction rather than only being an indicator of a systemic inflammatory response. IL-6 was proposed to be a mediator of important exercise-associated adaptive metabolic processes. This is in line with Pedersen (2012) and Pelacio-Gonzales et al. (2015).

The trajectory of nutritional status showed that the albumin/globulin ratio showed values below the normal range while crossing the Priestly glacier and were at the lower border of the normal range during the ascent. This could be viewed as an indication of malnutrition during these phases. Importantly, this was followed by recovery during the phase following the reduced ratio, which indicates that an energy consumption of 5000 to 6000 kcal is sufficient to maintain good nutritional status during extreme physical and fear inducing exposure.

A common factor in all parameters, except β-endorphin, was that emotional stress (i.e. fear) induced the highest levels of extracted biomarkers. This could have implications for the interpretation of neural causal pathways involved in energy consumption, and it could be inferred from studies of biomarkers that the ascending pathways are involved in cognitive experiences. The suggestion that IL-6 is a mechanism in muscle-brain crosstalk assumes the existence of ascending pathways from the periphery to the central nervous system causing a conscious awareness of for instance appetite. By showing that the experience of extreme fear has a profound effect, greater than changes caused by the physical apparatus (i.e. extreme physical activity), one could envision descending neural pathways from the brain to the periphery and not only the other way around. Although speculative, these descending pathways would be in addition to the internal emotional network within the brain and the descending motor pathways previous reported.

Limitations

There are some limitations to the studies presented here. First, there was a lack of control groups/subjects in all studies. The lack of control groups complicates the interpretation of the results because third-variables, i.e. variables not controlled for, could influence the results. Second, the generalizability of case studies is limited, and may be even more so when studying subjects operating in extreme environments. However, case studies of polar explorers have advantages in terms of increased control, including a lack of contamination due to infections and tight controls of energy intake and social support. Some caution should also be noted regarding the use of “wet” parameters as indicators of psychological processes. Several of the parameters used in the studies reported could be secreted as a consequence of different psychological processes and the same parameter could be released in different organs. For instance, β-endorphin has been shown to be released during feelings of reward as well as during nociceptive experiences. Another example is Il-6 that could be released by muscle contractions, but it could also be released at the site of an inflammation.

Conclusion

Studies presented in this overview, link personality hardiness to the adaptation process and performance in polar environments. It also adds to previous knowledge by involving biological markers that could be involved in the interplay between hardiness and adaptation to extreme environments. Fear, physical activity, appetite and nutritional status are conceivably the most critical factors during solo polar expeditions. The overview presents longitudinal data describing the trajectories of biological characteristics for these factors when high hardy subjects are involved in adaptation to extreme activity over prolonged periods of time. Generating knowledge related to adaptation and performance in extreme environments could influence activities ranging from mountaineering to deep-space exploration.

The marked impact of fear on biological markers of stress (cortisol), stress regulation (NY), inflammation (interleukins), appetite (leptin and adiponectin) and nutritional status (albumin and globulin), even superseding that of extreme physical strain, is an important finding that could fuel further research on biological mediators of a causal direction from subjective experience of emotions to physiological effects. The suggested evolutionary explanation is not previously reported as well as the somewhat speculative interpretation of descending neural pathways. The overview also present knowledge about the calories needed in order to recover during and after an expedition and could be used in the planning of future missions involving extreme exposure.

Another practical consequence of this overview is an indication of personality characteristics that can be used in selection of personnel to polar expeditions.

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Declarations

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