EFFECT OF THE ANTARCTIC ENVIRONMENT ON HORMONE LEVELS AND MOOD OF THE CHINESE EXPEDITIONERS

ABSTRACT

Background. Serum thyroid hormones, plasma catecholamines and mood were examined in 10 male members of the 16th Chinese Antarctic Expedition who spent the 2000 austral winter at Great Wall Station.

Study design. Samples were taken prior to deployment to Antarctica (December, 1999) and upon return to China 54 weeks later (December, 2000). The expeditioners also completed the Profile of Mood States (POMS) each month over an 8-month period (April through November, 2000).

Results. There was a significant decrease in levels of serum total thyroxine (p<0.01) and plasma epinephrine (p < 0.05), and a significant increase in serum TSH (p<0.01). With the exception of a significant decline in level of vigor (p=0.008), there were no significant changes in mood throughout the expedition. Low levels of pre- and post-deployment total triiodothyronine and high levels of TSH were significantly associated with high levels of tension-anxiety, depression, anger, confusion, and total mood disturbance at the beginning and end of winter. High levels of TSH were also significantly associated with high levels of fatigue (p < 0.001), while low levels of total thyroxine were significantly associated with high levels of tension-anxiety (p < 0.001), depression (p < 0.05), and total mood disturbance (p < 0.05). Low levels of dopamine were significantly associated with high levels of tension-anxiety (p < 0.05). An increase in anger during the austral winter was significantly associated with an increase in adrenaline during the expedition (p < 0.05). Conclusion. The increase in TSH, and its association with mood, is consistent with the polar T3 syndrome, while the absence of changes in free triiodothyronine and thyroxine may reflect characteristics of the environment, or racial/ethnic differences in psychophysiological, or socio-cultural adaptation to circum-polar environments.

Key words: Antarctic, expedition members, thyroid hormone, catecholamine, mood.
INTRODUCTION

Far from civilization, Antarctica is the most isolated of the earth’s continents. The harsh climate, severe cold, violent storms and the extreme diurnal cycle, all exert severe constraints on human habitation, accounting for the absence of indigenous residents. Only explorers, tourists and scientists step onto this continent for relatively brief periods of time. Long-term exposure to the extreme and isolated (geophysical and metaphysical) Antarctic environment is considered to be both physiologically and psychologically stressful. Adaptation to these stressors requires changes in the regulation of mood and metabolism to obtain psychophysiological homeostasis.

In 1984, China constructed the Great Wall Station (62°12'59''S, 58°57'52''W) on King George Island and dispatched her first Antarctic research expedition to conduct scientific investigation. Since then, a series of human physiological and psychological changes have been reported in expedition members staying and working at both the Great Wall Station and Zhong Shan Station (69°22’24’’S, 76°22’40’’E) (1-6). These changes include temporary declines of cardiac (7) and immune function (6). Changes in personality characteristics and psychological behaviours of some Chinese expedition members were also found, especially in winter. These included emotional instability with anxiety, depression, and sleep disturbances (3,4). An increase in desynchronization of electroencephalogram readings suggested stress on the hypothalamic-pituitary-adrenal (HPA) axis (6). This increase was accompanied by changes in endocrine function, which might play an important role in the physiological adaptation to the harsh polar environment. Our previous results showed that plasma cortisol and urinary adrenaline and noradrenaline were increased, but no data of plasma catecholamine were obtained (2).

Reed and colleagues (8-11) have found that Americans who live and work in Antarctica for longer than four to five months develop a characteristic constellation of symptoms and thyroid hormone changes called the polar T3 syndrome. Elevated thyrotropin stimulating hormone (TSH) and decreased total triiodothyronine (T3), and free T3 and thyroxine (T4) were found, and were associated with depressed mood (8). Seasonal changes in thyroid function concomitant with the polar T3 syndrome are significantly associated with changes in mood referred to as the winter-over syndrome (12). However, to date, these
findings have been largely restricted to investigations of American personnel in the Antarctic. It is unclear whether expeditioners from other nations experience similar patterns of psychophysiological adaptation to extreme polar environments. We might hypothesize, for instance, that differences in physiological adaptation to cold temperatures (13), or social and cultural adaptation to prolonged isolation and confinement (14, 15) in an extreme environment, might result in the manifestation of the polar T3 syndrome in some national expeditions to circumpolar settings, but not in others.

The objective of the present study was to examine the influence of prolonged Antarctic residence on neuroendocrine function and psychological behavior in members of the 16th Chinese Antarctic Winter-Over Expedition. Specifically, we wished to determine whether these individuals exhibited any significant changes in neuroendocrine function and mood after spending a year in the Antarctic, and whether there was any association between mood states and thyroid and adrenal medulla hormones.

METHODS

Subjects
Subjects for the study consisted of 10 male members of the 16th Chinese Antarctic Research Winter-over Expedition to the Great Wall Station, with an average age of 35.6 (SD = 6.5) years (range: 24-50). Everyone was required to be evaluated as medically and psychologically qualified for winter-over duty. Procedures for data collection and analysis were reviewed and approved by the Institutional Review Boards of the Peking Union Medical College and the University of California, San Diego. Informed consent was obtained from each participant after the study objectives and data collection procedures had been fully explained.

Expeditioners departed (December 10, 1999) from, and returned (December 24, 2000) to Beijing by airplane. In an effort to collect baseline data prior to the Antarctic and to control for the effects of environmental conditions on data collection, baseline (pre-expedition) and follow-up (post-expedition) blood samples were taken in the same location and at the same room temperature (22-25°C) in Beijing, 1 day before departure from Beijing to Antarctica (December 9, 1999, at...
7:30-8:00 AM) and 1 day after returning to Beijing (December 25, 2001, at 7:30-8:00 AM) from Antarctica, where they lived for approximately 54 weeks. Each individual was required to be fasting, sitting and had a rest for 30 min before venous blood was taken. The blood sample was divided into two parts, one part (for plasma catecholamine test) was anti-coagulated by heparin, and then centrifuged for 15 min (3000r/min) in 4°C. The other part (for serum thyroid hormone test) was allowed to clot at room temperature. The serum was then separated and stored at –70°C. All samples remained at this temperature until co-assayed.

**Measures**

*Serum thyroid hormone*

Levels of serum thyroid hormone, total triiodothyronine (TT3), free triiodothyronine (FT3); total thyroxine (TT4), free thyroxine (FT4) and thyroid stimulating hormone (TSH) were investigated by using Chemoluminescence Immunoassay (CLIA). TT3, FT3; TT4, FT4 and TSH were analyzed by using Automated Chemiluminescence’s System (ACS: 180) CHIRON reagent box from Bayer company of Germany. The main ingredients are: 1) TT3: monoclonal mouse anti-T3 antibody (~300 ng/vial) labeled with acridinium ester in buffered saline with sodium azide (0.1 %), sodium barbital, and l-anilino-naphthalene-8-sulfonic acid (ANS); 2) FT3: monoclonal mouse anti-T3 antibodies (~40 ng/vial) labeled with acridinium ester in HEPES buffer with protein stabilizers and sodium azide (0.1 %); 3) TT4: monoclonal mouse anti-T4 antibody (~5 µg/vial) labeled with acridinium ester in sodium barbital buffer with protein stabilizers, ANS, EDTA, and sodium azide (0.1 %); 4) FT4: acridinium ester-labeled T4 (~1.2 µg/vial) in sodium barbital buffer with protein stabilizers, sodium azide (<0.1 %), and EDTA; and 5) TSH: monoclonal mouse anti-TSH antibody (~1.67 µg/vial) labeled with acridinium ester in HEPES buffered saline with protein stabilizers, sodium azide (<0.1 %), and preservatives. The reference ranges for these assays are: FT3: 2.772-6.314 pmol/l, FT4: 10.449-24.381 pmol/l, TT4: 55.47-161.25 pmol/l, TT3: 1.016-2.957 nmol/l, TSH: 0.38-4.34 mU/l.

*Plasma catecholamines*

The levels of plasma catecholamines, including norepinephrine (NE), epinephrine (E) and dopamine (DA) were tested by High Performance
Liquid Chromatography with electrochemical detection (HPLC-ECD), according to the method of Cheng Lanying (16), using the catecholamine analytic instrument of the Weters Company. The main ingredients (purchased from the Sigma Company) are: norepinephrine (NE), epinephrine (E), normetanephrine (NMN), 3, 4-dihydroxyphenylacetic acid (DOPAC), dopamine (DA), metanephrine (MN), homovanillic acid (HVA), 3,4-dihydroxybenzylamine (DHBA).

Profile of Mood States (POMS)
In conjunction with another ongoing study of cultural differences in psychosocial adaptation to the austral winter in Antarctica (15), each month, over an 8-month period (April through November), the expeditioners were asked to complete the Profile of Mood States (POMS), a 65-item, self-report mood questionnaire that obtains data on six factors; five that assess negative mood or affect (tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia, and confusion-bewilderment), and one that assesses positive affect (vigor-activity) (17). A Total Mood Disturbance (TMD) score is derived by summing the scores of five of the subscales (tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia, and confusion-bewilderment) and subtracting the vigor-activity subscale score. The instrument has been found to exhibit high test-retest and internal consistency reliability in samples of the general population.

Statistical Analysis
Differences in pre-deployment and post-deployment measures of serum thyroid hormone and plasma catecholamines were assessed by means of paired samples t-tests. We also compared changes in thyroid hormone levels with changes in catecholamines between December 1999 and December 2000, using Spearman correlation coefficients. Repeated measures analysis of variance was used to determine if mood scores changed significantly over the course of the expedition. Two types of analyses were conducted to examine the association between thyroid hormones and catecholamine levels and mood scale scores. The first compared the thyroid hormones and catecholamines obtained prior to departure for Antarctica (December 1999) with the mood scores obtained at the beginning of the austral winter (April, 2000), and the thyroid hormones and catecholamines obtained upon return from Antarctica (December 2000) with the
mood scores obtained at the beginning of the austral summer (November, 2000) (Figure 1). Bivariate comparisons were conducted using Spearman correlation coefficients, while linear regression was used to determine whether the associations were independent of the timing of data collection (beginning, or end of the expedition) after variables with skewed distributions (tension-anxiety, depression, anger, fatigue and confusion) had been subjected to square-root transformation. The second set of analyses compared changes in hormone levels between December 1999 and December 2000 with changes in mood scale scores between April and November 2000, using Spearman correlation coefficients.

RESULTS

Changes in serum thyroid hormones and catecholamines.
After living in Antarctica for 1 year and 2 weeks, serum TT4 decreased (p <0.005), and TSH increased (p<0.01). No significant changes of serum TT3, FT3, or FT4 (p>0.05) were found (Table I). During the same period, Plasma E decreased significantly (p<0.05). Plasma DA decreased and plasma NE increased, but the changes were not statistically significant. Nevertheless, changes in levels of norepinephrine during the 54-week Antarctic deployment were significantly associated with changes in TSH (r =.687, p = 0.028).
Table I. Pre and post-Antarctic serum thyroid hormones and plasma catecholamines in 10 male members of the 16th Chinese Antarctic Expedition (mean ± SD)

|                               | 1 day before departure to Antarctica (Dec. 10, 1999) | 1 day after return to Beijing (Dec. 25, 2000) |
|-------------------------------|-----------------------------------------------------|---------------------------------------------|
| **Thyroid hormones**         |                                                     |                                             |
| TT3 (nmol/l)                 | 2.41 ± 0.39                                         | 2.40 ± 0.25                                 |
| FT3 (pmol/l)                 | 5.10 ± 0.34                                         | 5.28 ± 0.17                                 |
| TT4 (nmol/l)                 | 103.8 ± 15.07                                       | 93.23 ± 12.10***                           |
| FT4 (pmol/l)                 | 17.89 ± 2.08                                        | 18.37 ± 1.21                               |
| TSH (mU/l)                   | 1.54 ± 0.46                                         | 2.10 ± 0.53**                               |
| **Catecholamines**           |                                                     |                                             |
| Epinephrine (E) (pmol/l)     | 649.7 ± 207.5                                       | 387.7 ± 109.2*                             |
| Norepinephrine (NE) (pmol/l) | 3729 ± 780.1                                        | 4042 ± 1158                                |
| Dopamine (DA) (pmol/l)       | 385.3 ± 404.9                                       | 202.4 ± 169.8                              |

* = p < 0.05, ** = p < 0.01

Changes in mood

Average monthly scores on the POMS mood subscales, from March through November, are indicated in Figure 2. With the exception of a significant decline in the level of vigor (p=0.008), there were no significant changes in mood during this period.

Figure 2. Changes of mood of Antarctic expedition members, by month, from April through November.
The association between hormone levels and mood scores

Low levels of Total T3 and high levels of TSH at the beginning (December 1999) and end (December 2000) of the expedition were significantly associated with high levels of tension-anxiety, depression, anger, confusion, and total mood disturbance at the beginning (April, 2000) and end (November, 2000) of the austral winter in Antarctica, respectively (Table II). High levels of TSH were also significantly associated with high levels of fatigue, while low levels of total T4 were significantly associated with high levels of tension-anxiety, depression, and total mood disturbance. Low levels of dopamine were significantly associated with high levels of tension-anxiety. With the exception of total T4 and depression/total mood disturbance, these associations persisted after controlling for the timing of the data collection (at the beginning and end of the expedition).

The association between changes in hormone levels and changes in mood scores is described in Table III. In contrast to the cross-sectional comparisons at the beginning and end of the expedition, increases in tension-anxiety, depression, anger, fatigue and confusion were more strongly correlated with a decrease in free T3 than with total T3. However, these correlations were not statistically significant. An increase in TSH during the expedition was significantly associated with increases in fatigue and total mood disturbance, while an increase in anger significantly associated with an increase in adrenalin.
Table III. Spearman rank order correlations of changes in mood from the beginning to the end of the austral winter (April and November, 2000) with thyroid hormones and catecholamines from the beginning to the end of the expedition (December 1999 and December, 2000).

| Mood               | Thyroid hormones | Catecholamines |
|--------------------|------------------|----------------|
|                    | Total T3 | Free T3 | Total T4 | Free T4 | TSH | NE | E | DA |
| Tension-anxiety    | -.19     | -.43    | -.33     | -.36    | .59  | .33 | .14 | .00 |
| Depression         | -.12     | -.36    | -.31     | -.29    | .52  | .31 | .21 | .02 |
| Anger              | .11      | -.59    | .37      | .07     | .06  | -.18 | .71* | .40 |
| Vigor              | -.17     | -.62    | .55      | -.10    | -.17 | -.41 | .52  | .24 |
| Fatigue            | -.33     | -.55    | -.29     | -.64    | .79* | .69 | .02 | -.38 |
| Confusion          | -.83     | -.50    | -.06     | -.67    | .46  | .11 | .02 | -.22 |
| Total mood disturbance | -.31     | -.45    | -.36     | -.50    | .71* | .50 | .07 | -.17 |

*p<0.05

DISCUSSION

The significant increase in TSH in this cohort of Chinese Antarctic expeditioners is consistent with the changes in thyroid function of American Antarctic expeditioners after extended Antarctic residence reported by Reed and colleagues (18). Known as the Polar T3 Syndrome, these changes are also characterized by a small decline in serum free T3 (FT3) and free T4 (FT4), a doubling in both T3 distribution volume and plasma appearance and clearance rate, as well as a small decrease in T4 distribution volume (10). However, apart from the significant decline in total T4 (TT4), these additional changes were not observed in the Chinese expeditioners.

Also consistent with the findings of previous research (8, 12), the thyroid hormone levels of the Chinese expeditioners were significantly associated with mood states. In particular, low levels of total T3 and total T4 and high levels of TSH in serum samples collected in China before and after the expedition were significantly associated with high levels of tension-anxiety, depression, anger, confusion, and total mood disturbance in POMS data collected in Antarctica before and after the austral winter. Moreover, an increase in TSH from baseline to the end of winter was significantly associated with increases in fatigue and total mood disturbance. These mood changes in Antarctic expeditioners have been referred to in the past as the winter-over synd-
and also occur in patients with clinical hypothyroidism (20) and subclinical hypothyroidism (21). Nevertheless, the only significant change in mood experienced after one year of Antarctic residence at the Great Wall Station was a decline in vigor, or energy.

There are two potential explanations for the difference in patterns of mood disturbance and alteration of thyroid function in the Chinese expeditioners and other Antarctic expeditioners. First, this study examined only measures of thyroid function obtained prior to deployment to the Antarctic and upon return to China and thus was not able to examine the circannual pattern of thyroid function observed in previous studies (8, 12). As noted in Figure 2, POMS scores exhibited no clear linear trend from one month to the next, but rather increased during the months of May, July, September and November, and declined during June, August and October.

Second, the differences in mood may reflect cultural differences in patterns of adaptation to isolated and confined extreme (ICE) environments. Previous research reported by Palinkas and colleagues (15) found similar declines in levels of vigor at China’s Great Wall Station, Russia’s Vostok Station, India’s Maitri Station, Poland’s Arctowski Station, and the United States’ South Pole Station. However, this study also found a significant increase in fatigue and tension-anxiety at the South Pole, a significant decline in fatigue and anger at Maitri Station, and significant declines in depression, tension-anxiety and confusion at Vostok Station. These differences may be attributed to differences in environment (reflected in terms of latitude, temperature and altitude), as well as differences in culture-determined responses to environmental and psychosocial stressors (15). For instance, despite similar physical environments, tension-anxiety increased at South Pole Station and decreased at Vostok Station. Despite the proximity of the two stations, Chinese expeditioners at Great Wall Station exhibited higher levels of depression and confusion, and lower levels of anger, than Polish expeditioners at Arctowski Station.

A significant decline in levels of plasma epinephrine was also observed in this cohort of Chinese expeditioners. Research indicates that thyroid function may be regulated by the hypothalamic-pituitary-adrenal (HPA) axis (22), as well as through the negative feedback mechanism of the hypothalamic-pituitary-thyroid (HPT) axis. Epinephrine may stimulate the thyroid gland to release thyroid hormone. Changes in internal (i.e. psychosocial), or external (i.e. environmental)
stressors may activate the HPA pathway, thereby stimulating TRH. However, in this study, although increasing plasma epinephrine was associated with increases in anger, epinephrine levels in general decreased after a year of extended Antarctic residence. On the other hand, the increase in norepinephrine over the course of the expedition, while statistically nonsignificant, was found to be significantly associated with the increase in TSH. Diminished metabolism caused by hypothyroidism results in reduced heat production and body core temperature (22). As a counter-regulatory response, the sympathetic activity is increased, presumably both locally in tissues (high levels of norepinephrine) and systemically (high levels of epinephrine) (23). Other factors besides the increased sympathetic activity that may account for the increase in TSH in circumpolar settings include low body temperature, photoperiod, a decrease in the levels of circulating FT4, dietary iodine, decreased androgen levels, or cytokine alterations (8). Further research is required to determine the role of these potential mechanisms in the polar T3 syndrome.

Also in need of further investigation is the direction of causality between changes in thyroid function and changes in mood. Palinkas and colleagues (12) noted that, while declines in levels of free T3 and free T4 preceded increases in tension-anxiety and confusion in a cohort of American expeditioners at McMurdo Station, increases in tension-anxiety and total mood disturbance also preceded a decline in free T3 levels. Alterations in thyroid hormones in polar environments are believed to result from physiological adaptation to cold temperatures and are associated with changes in metabolic rate (8, 24). Further, Reed et al. (8) found that a low dosage (50 µg) of L-thyroxine supplement significantly improved cognitive performance after 4 months of Antarctic residence. However, these changes may also be the result of the activation of the HPA and HPT axes by psychosocial stressors. This is supported by Grossoles and Leloup (25), who found that plasma T4 decreased to one-third of normal levels found in fasting emperor penguins after confinement, but not in unconfined fasting penguins.

Several limitations may have contributed to the limited statistical significance of otherwise high correlations between mood and hormone levels. These include the small number of subjects and the disjunction in the timing of the collection of the hormone measures and the mood scores. Nevertheless, the results demonstrate an association
between alterations in neuroendocrine function, characterized by changes in thyroid hormones and catecholamines, and alterations in behavior, characterized by changes in mood, during prolonged exposure to isolated and confined polar environments. Although the changes in thyroid function do not appear to be as extensive as the changes that characterize the Polar T3 Syndrome in other Antarctic expeditioners, these results suggest that Chinese expeditioners might benefit from the use of low dosage thyroid supplements in preventing the declines in mood and cognitive performance that occur during the austral winter in Antarctica.

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