Medical Hypotheses 81 (2013) 547–550

Contents lists available at SciVerse ScienceDirect

Medical Hypotheses

journal homepage: www.elsevier.com/locate/mehy

High altitude syndromes at intermediate altitudes: A pilot study in the Australian Alps

Graham Slaney [a,*], Angus Cook [b], Philip Weinstein [c]

[a] Mansfield Medical Clinic, 49 Highett Street, Mansfield, Victoria 3724, Australia
[b] School of Population Health, University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia
[c] Barbara Hardy Institute, University of South Australia, GPO Box 2471, Adelaide, South Australia 5001, Australia

ARTICLE INFO

Article history:
Received 16 March 2013
Accepted 3 July 2013

ABSTRACT

Our hypothesis is that symptoms of high altitude syndromes are detectable even at intermediate altitudes, as commonly encountered under Australian conditions (<2500 m above sea level). High altitude medicine has long recognised several syndromes associated with rapid ascent to altitudes above 2500 m, including high altitude pulmonary oedema (HAPE), high altitude cerebral oedema (HACE) and high altitude flatus expulsion (HAFE). Symptoms of high altitude syndromes are of growing concern because of the global trend toward increasing numbers of tourists and workers exposed to both rapid ascent and sustained physical activity at high altitude. However, in Australia, high altitude medicine has almost no profile because of our relatively low altitudes by international standards. Three factors lead us to believe that altitude sickness in Australia deserves more serious consideration: Australia is subject to rapid growth in alpine recreational industries; altitude sickness is highly variable between individuals, and some people do experience symptoms already at 1500 m; and there is potential for an occupational health and safety issue amongst workers.

To test this hypothesis we examined the relationship between any high altitude symptoms and a rapid ascent to an intermediate altitude (1800 m) by undertaking an intervention study in a cohort of eight medical clinic staff, conducted during July of the 2012 (Southern Hemisphere) ski season, using self-reporting questionnaires, at Mansfield (316 m above sea level) and at the Ski Resort of Mt Buller (1800 m), Victoria, Australia. The intervention consisted of ascent by car from Mansfield to Mt Buller (approx. 40 min drive). Participants completed a self-reporting questionnaire including demographic data and information on frequency of normal homeostatic processes (fluid intake and output, food intake and output, symptoms including thirst and headaches, and frequency of passing wind or urine). Data were recorded in hourly periods extending over 18 h before and 18 h after ascent.

We found that the frequency of flatus production more than doubled following ascent, with a post-ascent frequency of approximately 14 expulsions per person over the 18 h recording period (Rate Ratio 2.31, CI 1.33–3.99, $p = 0.003$). The frequency and severity of headaches also increased following ascent. These results support the hypothesis that high altitude symptoms can be significant issues even at the relatively lower altitudes encountered in Australian alpine regions. Increased awareness amongst clinicians of this possibility could contribute to a reduction in the disease burden from high altitude syndromes at intermediate altitudes.

Introduction/background

High altitude medicine has long recognised several syndromes associated with rapid ascent to altitudes above 2500 m, including high altitude pulmonary oedema (HAPE) and high altitude cerebral oedema (HACE). More recently, Auerbach and Miller [1] proposed the term high altitude flatus expulsion (HAFE) for the increased flatulence experienced by recreational mountain users ascending to similar heights. Symptoms of high altitude syndromes are of growing concern because of the global trend toward increasing numbers of tourists, hikers, skiers, mountain bike riders, support staff and hospitality industry workers exposed to both rapid ascent and sustained physical activity at high altitude. Long-haul airline passengers and crews are also at risk, as has been recently highlighted in relation to potential social complications [2], because cabin pressures are generally maintained at a pressure equivalent to an altitude of 2400 m [3] and again there is a global trend toward increasing both the number and length of such flights. In

* Corresponding author. Address: Mansfield Medical Clinic, P.O. Box 138, Mansfield, Victoria 3724, Australia. Tel.: +61 3 5775 2166; fax: +61 3 5775 2533.
E-mail address: gslaney@people.net.au (G. Slaney).

0306-9877/$ - see front matter
http://dx.doi.org/10.1016/j.mehy.2013.07.002

Australia, high altitude medicine has almost no profile for domestic travellers and tourists, because of our relatively low altitudes by international standards (highest peak Mt Kusciuszko, 2228 m). However, three factors lead us to believe that altitude sickness in Australia deserves more serious consideration. Firstly, Australia is also subject to rapid growth in alpine recreational industries: At Mt Buller (1800 m), Victoria, the recent development of extensive mountain bike trails has quadrupled trail use in 3 years [4], adding to the over 114,000 annual summer visitors [5], and the existing 380,000 annual snow sports users [6]. Secondly, altitude sickness is highly variable between individuals, and some people do experience symptoms already at 1500 m [3] – leaving visitors to all of our ski-resorts in both Victoria and New South Wales vulnerable. Finally, there is a potential for an occupational health and safety issue amongst, for example, health care workers who could be subject to altitude-related exacerbations of already disrupted sleep patterns [7]. For these reasons, we carried out a trial to determine if we could establish any evidence for a relationship between self reported symptoms of high altitude syndromes and rapid ascent to an altitude commonly encountered under Australian conditions (1800 m).

Hypothesis

Our hypothesis is that symptoms of high altitude syndromes are detectable even at intermediate altitudes, as commonly encountered under Australian conditions (<2500 m above sea level).

Evaluating the hypothesis: materials/methods

To test this hypothesis we examined the relationship between any high altitude symptoms and a rapid ascent to an intermediate altitude (1800 m, Mt Buller), as commonly encountered under Australian conditions.

Our trial consisted of an intervention (ascent) study in a small cohort of medical clinic staff. The study was undertaken in Mansfield at 316 m above sea level and at the Ski Resort of Mt Buller, Victoria, Australia, about 1800 m above sea level.

Subjects

The study participants were selected from staff volunteers working at the Mt Buller Medical Centre during the winter ski season. All staff (medical, nursing and clerical) working at the Centre were asked if they would be interested in participating, and if so were given an information sheet and provided with an opportunity to ask questions about the study objectives and procedure. So as to minimise the potential for reporting bias, the objectives were cast in terms of investigating homeostatic adjustment at altitude for a broad range of outcomes (below). Participants were asked to sign a consent form and the details of how to complete the self-reporting diary were provided. Ethics approval was obtained for the study from the Human Research Ethics Committee at the University of South Australia (2012, Number 29003).

Information collected

A total of eight staff agreed to participate, a convenience sample recruited to inform this pilot study. Participants were asked to complete a questionnaire consisting of demographic data as well as information on frequency of normal homeostatic processes such as fluid intake and output, food intake and output, and reported symptoms such as thirst and headaches. We did not record flatus volume or urine volume, but used frequency of passing wind or urine as surrogate indicators of the total amount of flatus or urine produced, respectively. Data were recorded in hourly periods (except when sleeping), extending over a defined period of 18 h before and 18 h after arriving at the Medical Centre. For headaches, severity was recorded concurrently on a scale of 1 (mild) to 5 (severe).

Analysis

Estimates of symptom frequency in the subjects relative to altitude shift were generated using Generalized Estimating Equations (GEE). Negative binomial models with an exchangeable correlation structure were chosen for the count data given over-dispersion of the data. Rate ratios and confidence intervals/*p*-values were calculated to compare symptom frequencies in the 18-h intervals immediately before and after the intervention (ascent).

Empirical data

The frequency of various symptoms, before and after ascent, are given in Table 1, with associated rate ratios and probabilities. The frequency of flatus production more than doubled following ascent, with a post-ascent frequency of approximately 14 expulsions per person over the 18 h recording period (Rate Ratio 2.31, CI 1.33–3.99, $p = 0.003$). This level of flatus expulsion is a conservative estimate, because expulsions during sleep were not recorded. A representation of the time series for flatus production by participant is given in Fig. 1, and shows the increased flatulence as well as the fact that peak expulsion rates were delayed by many hours post-ascent. The total number of expulsions recorded post-ascent was 113, about half of which (47%) were expelled between 8 and 11 h post-ascent, with the modal hour of expulsion being the 10th (24% of all expulsions).

The frequency (Table 1) and severity (Fig. 2) of headaches also increased following ascent. The frequencies of belching, urination (altitudinal diuresis) and thirst tended to also increase following ascent, but these differences were not statistically significant.

There was no significant difference in fluid consumption before and after ascent (6.6 and 7.8 drinks per hour respectively; paired *t*-tests, $p = 0.396$), nor was there any difference in food consumption (2.4 meals/snacks per hour both before and after; $p = 1.000$).

Consequences of the hypothesis and discussion

Our study of the relationship between symptoms of high altitude syndromes and rapid ascent to intermediate altitude demonstrates a clear increase in the frequency of flatus expulsion

Table 1
GEE estimates of symptom frequency relative to altitude shift immediately post- versus pre-ascent (arrival), for five of the symptoms recorded.

Symptom	Frequency of symptom*	Rate ratio ($\exp(\beta_i)$) + 95% CI	*P*-value
Belching	Before vs. after: 34/41	1.21 (0.68, 2.15)	0.527
Urination	Before vs. after: 27/36	1.33 (0.56, 3.20)	0.520
Flatus	Before vs. after: 49/113	2.31 (1.33, 3.99)	0.003**
Sensation of thirst	Before vs. after: 22/33	1.50 (0.59, 3.79)	0.391
Headache	Before vs. after: 4/23	5.75 (1.33, 24.95)	0.019**

* Across eight subjects each followed for 18 h immediately pre- and 18 h post arrival, excluding periods of sleep.
** Significant finding ($p < 0.05$).