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ORIGINAL ARTICLE

Acute mountain sickness in western tourists around the Thorong pass (5400 m) in Nepal

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Acute Mountain Sickness (AMS) was studied using a questionnaire for trekkers climbing a 5400 m high pass in the Nepalese Himalaya. Over 8 days, 500 questionnaires were issued to 530 trekkers on the way to the pass. A total of 371 questionnaires was returned, and 353 were used for analysis. Trekkers with scores over 0.7 for AMS-C (cerebral ESQ-III score) and/or 0.6 for AMS-R (respiratory ESQ-III score) were considered to suffer from AMS. The overall prevalence of AMS was 63%; the prevalence of AMS-C was 43% and of AMS-R was 57%. AMS was positively correlated with rate of ascent and negatively correlated with pre-trek acclimatization. Women suffered more frequently and more seriously from AMS. Body mass index (weight/length^2) was significantly correlated with AMS in men. No significant association was found between AMS and age, smoking habits, use of oral contraceptives, previous high altitude experience, special pre-trek training, size of trekking party or whether the trek was agency- or self-organised. Of trekkers, 80% had elementary knowledge of the diagnosis and treatment of AMS.

Introduction

The number of people that spend their holidays trekking in the Nepalese Himalaya has nearly quadrupled in ten years [1], and these trekkers run the risk of developing Acute Mountain Sickness (AMS).

AMS is a symptom-complex found in otherwise normal healthy individuals at altitudes above 2500 m. Most likely due largely to the lower partial oxygen-pressure found at high altitudes, it is usually benign and self-limiting. It may be recognized by a combination of several of the following symptoms: headache, lightheadedness, weakness, insomnia, anorexia, nausea, vomiting and shortness of breath. The more rapid the ascent and the higher the altitude reached, the more severe AMS [2–5] will be. Although the relationships are not yet completely delineated, it seems that benign AMS may proceed to two malignant life-threatening illnesses, high altitude cerebral edema (HACE)[6] and high altitude pulmonary edema (HAPE)[7]. Regularly, climbers and trekkers die with these illnesses [1].

One of the most popular trekking circuits in Nepal is that around the Annapurna massif. Each year, roughly 10 000 western tourists climb over the Thorong pass (5400 m), the highest point on the trek (Shlim, personal communication). The aim of the study was to describe the epidemiology of AMS on this particular trek that crosses a mountain pass.

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Methods

Over eight days in November 1986, a questionnaire was issued to trekkers on their way to the Thorong pass. Completed questionnaires were returned on the opposite side of the pass. The 530 trekkers that passed during this period were handed a total of 500 questionnaires, 479 in Manang and 21 on the Muktinath side of the pass (Fig. 1). A total of 371 questionnaires was returned, of which 18 were inaccurately completed and subsequently discarded. The remaining 353 were used for statistical analysis.

The questionnaire consisted of two parts. The first asked each subject to respond to questions on variables such as sex, age, height, weight, health, special pre-trek training, previous high altitude experience, knowledge of AMS, and rate of ascent on this trek. This part had to be completed in Manang the night before proceeding to the pass. A second part consisted of several copies of the Environmental Statistical Questionnaire III (ESQ-III) [8] for consecutive days spent between Manang and Muktinath going over the pass. This 67-question symptom inventory has demonstrated its validity reliably to identify persons who suffer from AMS [8,9]. The scores for the different AMS-associated questions (e.g. headache graded from 0 to 5) are multiplied by a factorial weight, totaled, and adjusted to a score from zero to five for a cerebral complex (AMS-C) and a respiratory complex (AMS-R). The thresholds of detection for AMS as given by Sampson *et al.* [8] were used. Trekkers who scored higher than 0.7 for AMS-C or 0.6 for AMS-R were considered to suffer from AMS. AMS-C related questions were on light-headedness (factorial weight 0.489), headache (0.465), dizzyness (0.446), faintness (0.346), dim vision (0.501), loss of coordination (0.519), weakness (0.387), stomach sickness (0.347), lost appetite (0.413), feeling sick (0.692), and feeling 'hangover'

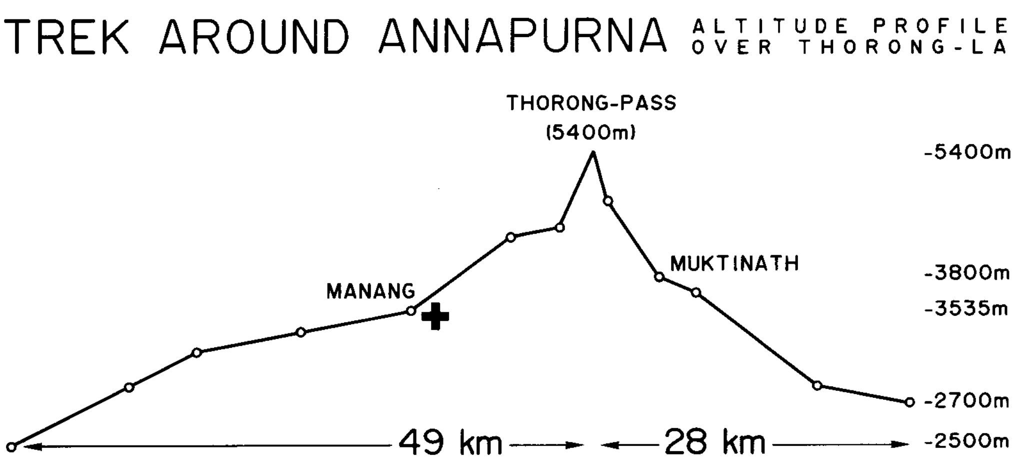

Fig. 1. Altitude profile over the Thorong pass. The open circles indicate villages or camping places where trekkers spend the night. Note the steepness above Manang and the difference in steepness on both sides of the pass. The 49 and 28 km are approximate trekking distances.
+: Himalayan Rescue Association Aid Post

(0.584). AMS-R related questions were on headache (0.312), shortness of breath (0.745), difficulty breathing (0.763), painful breathing (0.734), stomach cramps (0.516), backache (0.686), stomachache (0.774), stomach sickness (0.691), stuffed nose (0.534), nosebleed (0.578), sleeplessness (0.355), and depressed feeling (0.480). The results of AMS-C and AMS-R are presented separately, since AMS-C corresponds best with the clinical assessments used by other investigators.

Each night between Manang and Muktinath crossing the Thorong pass, the trekkers filled out an ESQ-III (Fig. 1). They were instructed to record the maximum scores experienced in the preceeding 24 h. In the analysis, the AMS (-C and -R) values scored in Manang (or Muktinath, depending on the direction of trekking) and the maximum values scored in one of the completed ESQ-IIIs were used.

As a parameter of speed of ascent, I chose cumulative altitude, which represents the sum of the altitudes (in meters) where the trekker spent the five nights before starting towards the pass from Manang (or Muktinath). Other variables that were studied are listed in Table 1.

The software package Systat 3.0 (Systat, Inc, Evanston, Il, USA) was used for statistical analysis. Differences between subgroups of the population were evaluated by the independent samples *t*-test; for simple relationships, the Pearson correlation was used. Prevalences in men and women and counts for different categories were compared where appropriate with the chi-square test. Subjects are represented only once in the various tests. Significance was assumed for $p < 0.05$.

Table 1. Different variables used, with dimensions

AMS-C and AMS-R scores	arbitrary units, from 0 to 5, see methods section
Cumulative altitude	the sum of the sleeping altitudes of the 5 days preceding the departure from Manang towards the pass, in meters
Daily altitude gain	mean gain in sleeping altitude per day in the 5 days preceding the departure from Manang towards the pass, in meters
Size of trekking party	number of persons in a group trekking together, in number
Smoking	three categories: no smoking, and smoking less or more than ten cigarettes per day
Altitude experience	three categories: never been to altitude, been higher than 2500 m but not higher than 3500 m, been over 3500 m
Training for this trek	did or did not prepare for this trek with some extra physical exercise
Prior acclimatization	three categories; no acclimatization prior to this trek, been higher than 4000 m between 2 and 4 weeks before this trek, been higher than 4000 m within 2 weeks of this trek
Prevalences	number of ill persons per number of persons at risk, expressed in percentages

Results

Prevalence

The overall prevalence of AMS in the studied population was 63%. The prevalence of AMS-C was 43% and that of AMS-R was 57%. In 38% of the questionnaires, both AMS-C and AMS-R were higher than the thresholds used.

Rate of ascent

Trekkers having symptoms of AMS-C in reaching Manang spent significantly less days between 2500 m and Manang (3535 m) than did trekkers who were not sick (independent samples t-test, $n = 353$, means 4.1 ± 1.1 and 4.5 ± 1.0 days, $p < 0.02$). These trekkers also had significantly less cumulative altitude than did trekkers who were not sick (independent samples t-test, $n = 353$, means 13452 ± 1608m and 14272 ± 1705 m, $p < 0.005$). Likewise, it was found that trekkers who had AMS-C on the Thorong pass had significantly less cumulative altitude than did trekkers who were not sick (t-test, means 13903 ± 1721 m and 14318 ± 1692 m, $p < 0.05$). Significance was not reached for AMS-R.

66% of the trekkers took 2 days and 33% took 3 days to cross the pass between Manang and Muktinath. These groups were not significantly different from each other with respect to AMS, when compared with the chi-square test.

Only 6% of the trekkers climbed the pass from the steeper Muktinath side of the pass (Fig. 1). Although their cumulative altitude was significantly lower (t-test, 12741 ± 1725 versus 14 249 ± 1650 m, $p < 0.001$) there was no significant difference in prevalence or degree of AMS.

Sex

The prevalence for AMS was 69% for women versus 57% for men (chi-square test, $p < 0.05$). For AMS-C, women scored 49% and men 39% (chi-square test, $p = 0.062$, n.s.). For AMS-R, women scored 64% and men 53% (chi-square test, $p < 0.05$). The scores for AMS-C and for AMS-R were greater in women than in men (Table 2). Men and women were comparable with regard to other characteristics (Table 2).

Other parameters

Age was negatively correlated with speed of ascent (Pearson correlation, $n = 353$, $r = -0.131$, $p < 0.05$) and positively with body mass index (BMI = weight/length^2, Pearson correlation, $n = 353$, $r = 0.190$, $p < 0.05$).

Male trekkers who suffered AMS around the pass had significantly higher BMI than those who were not sick (AMS-C; t-test, $n = 193$, means 23.1 ± 2.5 and 22.5 ± 2.4, $p < 0.005$; AMS-R: t-test, $n = 193$, means 22.9 ± 2.4 and 21.9 ± 2.4, $p < 0.005$). Conversely, the results were not significant for women.

Acute mountain sickness was not significantly associated with the following variables: previous altitude experience (52% had been at altitude before), smoking habits (24% smoked less and 4% smoked more than 10 cigarettes per day), pre-trek training (26% trained for the trek), oral contraceptives (21% of the women between 25 and 35 years of age used oral contraception), number of trekkers in the party or the method of organization (package deal from an agency or self-organized private party).

Analgesics, such as aspirin or paracetamol (acetaminophen), were used by 17% of

Table 2. Different variables for 193 men and 160 women, compared (± SD)

	Men	*Women*	*t-test, p, t*
Age	30.6 ± 7.6	30.1 ± 8.5	n.s., $t = 0.65$
AMS-C score	0.68 ± 0.65	0.91 ± 0.84	$p < 0.01$, $t = 2.73$
AMS-R score	0.76 ± 0.57	0.98 ± 0.76	$p < 0.01$, $t = 3.06$
Cumulative altitude	14134 ± 1760	14227 ± 1588	n.s., $t = 0.52$
Daily altitude gain	223 ± 74	231 ± 57	n.s., $t = 1.17$
Size of trekking party	5.4 ± 6.5	5.3 ± 5.5	n.s., $t = 0.13$
	Men	*Women*	*chi²-test, p,* χ^2
Smoking	17%	13%	n.s., $\chi^2 = 0.82$
Altitude experience	56%	47%	n.s., $\chi^2 = 3.45$
Training for this trek	24%	28%	n.s., $\chi^2 = 1.28$
Prior acclimatization	10%	11%	n.s., $\chi^2 = 0.19$
Overall AMS prevalance	57%	69%	$p < 0.05$, $\chi^2 = 5.27$
AMS-C prevalance	39%	49%	n.s., $p = 0.062$, $\chi^2 = 3.48$
AMS-R prevalance	53%	64%	$p < 0.05$, $\chi^2 = 4.26$

trekkers for headaches while crossing the pass. Use of these drugs was positively correlated with AMS (Pearson correlation, $n = 353$, $r = 0.168$, $p < 0.05$). Less than 2% used acetazolamide prophylactically [10], which was too small a subpopulation for statistical analysis.

Of the trekkers, 80% had elementary knowledge about diagnosis and treatment of AMS (knowledge of at least 2 symptoms; descent listed as the most important treatment). 67% of these had gained their knowledge from books on trekking, and 21% from lectures. Some 3% had never heard of altitude sickness before arriving in Manang.

Discussion

Prevalence

In this study, the overall prevalence of AMS was 63% in spite of knowledge of AMS in 80% of the trekkers. Hackett and Rennie, in their first study in trekkers on the way to Everest base camp, found an overall prevalence of 53% in 278 trekkers [3]. In a study two years later, they found a decrease to 43% ($n = 200$), and postulated that this could be an effect of better knowledge about AMS among trekkers [11]. Their results are not entirely comparable to ours, since they used different methods, including clinical examination, and performed their studies at one single location at 4200 m.

The prevalence of malignant AMS (HAPE and HACE) was estimated from observations around the pass and the cases that presented at the aid-post in Manang. In a two-month period, one person died of pulmonary edema after continuing on horseback in spite of symptoms of AMS. Two people with pulmonary edema were evacuated by helicopter. Many witnesses informed us that trekkers regularly staggered over the pass with ataxia, vomiting or other signs of more severe AMS. Recently, Shlim *et al.* [1] reported that although the number of people trekking in Nepal has increased dramatically in the last ten years, the number of deaths due to AMS has not changed much. This suggests increased trekker awareness concerning the medical risks of high altitude.

Bias

Factors that could have influenced the results of the present study are (1) the questionnaire was written in English, which was a foreign language for 46% of the respondents (Table 3); (2) most of the trekkers attended a lecture on AMS at the Himalayan Rescue Association aid post before climbing the pass, which may have had a preventive effect; (3) observations around the pass gave the impression that some trekkers were too sick to bother with the questionnaire; and (4) 17% of the trekkers used analgesics for headache and some trekkers used acetazolamide prophylaxis [10] against AMS; both modalities probably diminished the AMS scores.

Risk factors

The rate of ascent was a risk factor, as has been shown in previous studies [2,3]. The fact that the relative weight of this risk factor in this study was not very important (although significantly different, the mean values of the different groups were very close) can be explained by the fact that the trek up to Manang has a quasi-ideal profile of ascent (Fig. 1). Although never directly investigated, it is generally accepted that an important preventive measure against AMS is to limit the daily gain in sleeping altitude to 300–400 m above an altitude of 2500–3500 m, and to take a rest day after every 1000 m gained in altitude. The mean daily altitude gain up to Manang for trekkers climbing the Thorong pass from the Manang side ($n = 336$) was only 226 ± 67 m. However, most trekkers, after a day's rest in Manang, take only 2–3 days to cover the 1900 m difference in altitude between Manang and the Thorong pass, of which the last 1000 m up to the pass are climbed in one day (Fig. 1). One may conclude that up to Manang, trekkers climb cautiously (so that the influence of rate of ascent is limited to persons very sensitive to altitude), but over the final distance to the pass, all trekkers climb too fast, in spite of symptoms in the majority.

Most of the trekkers (94%) climbed the Thorong pass from the less steep Manang side. The group studied from the other side, although climbing significantly faster, was too small for statistical analysis. However, trekkers in the present study who had been to altitudes above 4000 m (mostly in Tibet) within 1 month prior to the trek over the Thorong Pass suffered significantly less AMS, suggesting that acclimatization may indeed last for some time after descent [12].

AMS was positively correlated with BMI in men, confirming a recent report by Hirata

Table 3. Sex distribution and nationalities of the study population ($n = 353$)

Men	193 (55%)
Women	160 (45%)
USA + Canada	86 (24%)
Great Britain	62 (18%)
Australia + New Zealand	43 (12%)
France	43 (12%)
Germany	31 (9%)
Scandinavia	23 (7%)
Benelux	20 (6%)
Other countries	45 (13%)

et al. [13]. BMI is a good parameter of body composition in an average Western population [14] and gives a rough indication of an overweight condition. The only other report relating body composition and altitude exposure is from Boyer and Blume [15], who mention that subjects with a higher BMI tend to lose more weight. At sea level, extreme obesity may cause hypoventilation, leading in extreme cases to the Pickwickian syndrome. One might speculate that subjects with a high BMI relatively hypoventilate, thus rendering themselves vulnerable to AMS at altitude.

There is some evidence that susceptibility for AMS, HACE and HAPE is greater in the young [3, 16–18]. The observed small effect of age on AMS in the present study, however, may be explained simply by the fact that young climbers ascended faster.

Are women more susceptible to AMS than men? Hackett *et al.* found no difference in susceptibility between the sexes during trekking [3], while others have found that women are more prone to AMS than are men during climbing expeditions [19]. In the present study, men and women differed with regard to prevalence and degree of AMS (Table 2). There are other reports on differences between men and women with regard to hypoxia or altitude, like the hypoxic ventilatory drive that has been shown to change with the menstrual cycle [20], and a report of a higher prevalence of high altitude peripheral edema and high altitude retinal haemorrhage in women as compared with men [21].

Women are often advised not to use oral contraceptives at high altitude because of a supposed increased risk of thromboembolic incidents. Although 21% of the women in this study used oral contraceptives, no thromboembolic events were reported. However, it could be that the duration of the altitude exposure was brief enough to prevent these problems.

The total number of subjects and percentage of women were greater in this study than in previous ones [3,11], which may explain why some parameters like female gender and BMI were correlated with the prevalence of AMS. However, the relative importance of these variables is small, as shown by the closeness of different means and the small correlation factors. These variables do not appear to be useful in predicting susceptibility to AMS in an individual.

In conclusion, the prevalence of AMS on the Thorong pass encountered on the trek around the Annapurna massif is high, even in a well-informed population. More education might not lower the prevalence of benign AMS, but may further prevent morbidity from HACE and HAPE.

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