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# Tibetan plateau earthquake: altitude challenges to medical rescue work

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## ABSTRACT

**Background** Rescue efforts for earthquakes in remote plateau regions require large numbers of professional personnel to be transported from various lowland regions for relief work. Unacclimatised rescuers to high-altitude regions commonly suffer acute mountain sickness (AMS), which makes relief efforts inefficient and potentially dangerous.

**Methods** In this study, the AMS symptoms of 78 unacclimatised rescue workers for the Yushu earthquake from Beijing were recorded using the Lake Louise AMS self-report questionnaire. Heart rate and blood oxygen were recorded at rest before departure, during rest and during activity.

**Results** After ascending, resting heart rate increased from mean 75.87 bpm to 87.45 bpm and resting $SpO_2$ decreased from an average of 98.51% to 90.35% (both $p<0.001$). The mean Lake Louise AMS Score for participants was 3.1 (95% CI 2.6 to 3.6). 29 members (37.2%) met the diagnosis criteria for AMS. 16 members (20.5%) were evacuated early due to acute AMS (AMS score $\geq 5$). *Rhodiola* was offered on a voluntary basis as a prophylactic measure but shown to be ineffective.

**Conclusion** Given the ineffectiveness of prophylactic measures and the urgency of such disaster situations, it is unrealistic to mobilise rescue teams from lowland regions for immediate relief efforts. A local disaster plan specific to plateau earthquakes needs to be developed with local personnel for timely and efficient relief.

## BACKGROUND

Unacclimatised travellers to high-altitude regions commonly suffer acute mountain sickness (AMS), a series of symptoms caused by the low barometric pressure and low blood oxygen.[1 2] AMS is most serious among travellers who have not had adequate time to adapt to the high-altitude extreme environment. The incidence of high-altitude pulmonary oedema varies from 0.01% to 2% in most studies but has reached as high as 15.5% among soldiers flown directly to 14 500 feet without time to acclimatise.[3 4] The risk of developing AMS poses a significant challenge when rescue workers of lowland are recruited to participate in relief efforts involving disasters located at high altitudes.

In response to the 2010 Yushu earthquake (6.9 magnitude, 33.2N, 96.6W, Yushu County (average 14 400 feet), Qinghai province) on the Tibetan plateau, thousands of military medics and 1320 non-military medical personnel were recruited by the Ministry of Health for on-site emergency relief effort. These rescue workers were mostly lowland residents who must ascend rapidly to the disaster region. Some prophylactic measures for AMS are available such as the use of *Rhodiola* (a traditional Chinese medicine);[5] if effective, these could result in more efficient rescue activity. In order to fulfil the mission of medical rescue, the physiological changes and the manifestation of AMS were observed in all 78 medical rescue team members from Beijing (altitude 150 feet), and we also hypothesised that *Rhodiola* would protect against AMS.

## DATA COLLECTIONS AND METHODS

### Study group

Study participants were the 78 members of the Beijing Emergency Medical Center rescue team (age: 37.1±8.7 years, 73 male and five female members). Participants were mostly Han (n=76, 97.4%) with the exception of one Mongolian and one Hui (Muslim) ethnicity. The team consisted of 21 doctors, two nurses, 49 drivers and six administrators. Most team members did not have any known pre-existing medical conditions; one member had diabetes mellitus and one member had hypertension.

All participants were based in Beijing (altitude 150 feet). Four team members arrived by air (2.5 h flight) while the rest of the team (n=74) travelled by land from Beijing (34 h trip). The rescue team worked in Yushu County for 11 days, treating 518 patients and transferring 311 patients.

*Rhodiola*, a traditional Chinese medicine, was recommended to the team members 1 day before rapid ascent by the Public health administration but its use was voluntary. *Rhodiola* use was in two groups: *Rhodiola* preventive (n=46) and non-prevention (n=32). *Rhodiola* preventive individuals were given *Rhodiola rosea* 280 mg twice daily until evacuated to the plains. None of the participants took other medication for the prophylaxis of AMS such as acetazolamide (oral medical products were not available in China) or dexamethasone. All of them were told in advance that health administrators would provide oral acetaminophen (500 mg) as needed for headache. The two groups were comparable in age and gender.

### Study design

This is a prospective cohort study.

### Inclusion and exclusion criteria

The participants of this study include all 78 members of the Beijing EMS rescue team; participation in both the team and study was voluntary. Consent was obtained before the study began.

Pregnant women, obese persons (body mass index>25), elders (>55 years old), those with pulmonary and cardiovascular diseases were ineligible for safety concerns.

### Study protocol

Heart rate and pulse oxygen saturation were measured (Nellcor NPB-40 Handheld Pulse Oximeter) before departure in Beijing, on the second day of arrival, during rest in Yushu and after 30 min of work in Yushu, respectively. All subjects were given a questionnaire (Lake Louise AMS Self-report questionnaire) and instructed to complete it after descent to lower altitudes or before mandatory evacuation orders (the questionnaire was filled with the help of the administrators), reflecting maximal symptoms during the study period. The response rate was 100%. Symptoms were self-reported under five categories: headaches, gastrointestinal symptoms/nausea, fatigue, dizziness/light headedness and difficulty sleeping. Each category was reported on a scale of 0–3 with 0 as not suffering the symptom, 1 as mild, 2 as moderate and 3 as the symptom being incapacitating.[6]

An AMS diagnosis criterion for this study was having a headache and at least one other symptom with a total questionnaire score of 3 or greater.[6] Workers who had a Lake Louise AMS Score ≥5 or showed an altered mental state were evacuated to Xining (Altitude 8000 feet). Further manifestations of AMS, including cerebral and pulmonary oedema, were not recorded due to the lack of medical equipment on site.

### Statistical analysis

Data were entered and analysed using SPSS V.17.0 software package (SPSS Institute Inc.). All continuous variables are presented as the mean ± SD. Categorical variables were presented as frequencies or percentage. Comparisons of variables were performed using $\chi^2$ test, Fisher exact test (for instances in which cell counts were <5) and paired-sample t test. p Value<0.05 was accepted to be statistically significant.

## RESULTS

### High-altitude illness related symptoms

Chest tightness, headache and dizziness are the three most common symptoms (table 1). Sudden vomiting (n=7, 9.0%) is less common than nausea and anorexia (n=23, 29.5%) but was the most common symptom in those who were evacuated early (57.1% vs 16.9%, p=0.03).

### Heart rate and peripheral oxygen saturation changes before and after ascent

Rescue workers demonstrated hypoxia after ascent, and $SpO_2$ decreased from base (98.5%) to destination (90.3% rest and 79.3% active) (p<0.001). The change in heart rate from base (75.87 bpm) to destination (87.45 bpm rest and 112.01 bpm active) was also statistically significant (p<0.001) (table 2).

**Table 1** Clinical symptoms in rescue workers

| Symptoms | n (%) |
|---|---|
| Chest tightness | 53 (67.9%) |
| Headache | 36 (46.2%) |
| Dizziness | 33 (42.3%) |
| Shortness of breath | 28 (35.9%) |
| Nausea/anorexia | 23 (29.5%) |
| Insomnia | 13 (16.7%) |
| Palpation | 13 (16.7%) |
| Vomiting | 7 (9.0%) |
| Cough | 4 (5.1%) |
| Chest pain | 3 (3.8%) |

### AMS incidence and early evacuation

The mean Lake Louise AMS Score for participants was 3.1 (95% CI 2.6 to 3.6). Twenty-nine members (37.2%) met the diagnosis criteria for AMS. Sixteen members (20.5%) were evacuated early due to acute AMS (AMS score ≥5). Six (37.5%) of the early evacuations occurred on the day after arrival.

Of the four members who travelled by plane, one person (25%) was evacuated due to AMS. Of those travelling by train and road, 15 people (20.3%) were evacuated due to AMS. The incidence of AMS in the *Rhodiola*-treated group and the non-prevention group was 39.1% (18/46) and 34.4% (11/32), respectively.

### Follow-up

Rescue team members worked for an average of 7.0±2.8 days. After 13 days of work, all members of Beijing EMS rescue team left the scene. There were no deaths or hospitalisations of participants and a 1-year follow-up did not yield any long-term effects.

## DISCUSSION

### The necessity of a high-altitude medical rescue plan

Altitude sickness is a major concern for rescue workers from lowland regions. Rescue workers had no time to acclimatise and were highly active during their entire mission. AMS is common (67%) among mountain climbers who ascended rapidly (in 1–2 days) to 14 410 feet.[7] AMS incidence among unacclimatised soldiers travelling to Tibet (11 811 feet) is 57.2% (n=3628), with a hospitalisation rate of 12.07%.[8] Fatigue and excessive physical activity can also increase the incidence of altitude sickness.[9]

Many rescue workers had a pulse oxygen saturation of 60%–80%, average $SpO_2$ was 90% during rest, decreasing to 79% with activity; some individuals had pulse oxygen of 20%–40%. All 78 medical rescuers manifested some symptoms of AMS. Twenty-nine (37.2%) of the team members developed AMS and 16 personnel (20.5%) with moderate/severe AMS were evacuated early to a lower altitude region (lower than 8000 feet). In high-altitude rescue mission, altitude sickness threatens the health of rescue workers and decreases the efficiency of rescue operations. Prophylactic measures should be taken to acclimatise workers before ascent but the urgent nature of natural disasters limits the opportunity for acclimatisation before ascent. As an alternative to trying to acclimatise workers in such urgent situations, a plateau specific disaster plan that utilises local acclimatised staff is needed. Local personnel need little travel time, are already acclimatised, and can deliver aid that is both timely and efficient.

### Prophylactic intervention for high-altitude illness requires further study

Each medical team was equipped with emergency medical resources including surgical instruments, tetanus vaccine and antibiotics. Each rescue participant was also provided with a survival pack that included emergency equipment and

**Table 2** Heart rate and peripheral oxygen saturation changes before and after ascent

| | Before ascent rest (150 feet) | Disaster region (14 400 feet) | |
|---|---|---|---|
| | | Rest | Active |
| HR | 75.87±8.18 | 87.45±12.94* | 112.01±18.66† |
| $SpO_2$ | 98.51±1.67 | 90.35±7.60* | 79.33±8.75† |

*Compared with before ascend rest, p<0.001.
†Compared with disaster region rest, p<0.001.

**Table 3** Characteristics of earthquake DISASTER paradigm in plateau area*

| | | |
|---|---|---|
| D | Detection | Forecasting and announcing of earthquakes is difficult; however, early detection of casualties in the immediate aftermath is crucial. Warning systems, especially local sirens, are important due to the lack of radios and televisions. |
| I | Incident command | Language and cultural barriers must be accounted for. Initial rescue should be completed within the critical period (first 24 h) by local personnel. |
| S | Safety and security | The prehospital environment is unsafe, uncertain and unpredictable. Difficult weather and thin air are the potential challenges. |
| A | Assess hazards | Multiple hazards, such as aftershocks, building collapses, fires and explosions, are present in the affected area. An All-Hazards mindset is needed to minimise the risk these hazards present. |
| S | Support | The rescue team shall be equipped with sufficient outdoor survival and manual resuscitation equipment. The ICS must take into account the fact that transport and communications systems have been destroyed. |
| T | Triage and treatment | Rescuers should take into consideration the different physiological parameters of the local residents, as well as the special pathophysiological conditions of injuries. |
| E | Evacuation | Air evacuation of patients is preferred due to poor local sanitation and lack of operating healthcare facilities. A safe landing zone must be identified in the disaster plan. |
| R | Recovery | Critical incident stress management is necessary after the earthquake and requires aggressive planning. Public health hazards including plague, anthrax and enteric infection should be monitored and antibiotics should be prepared accordingly. Reestablishment of local healthcare facilities is crucial. |

*This paradigm was mainly adapted from DISASTER paradigm which was introduction in the Basic Disaster Life Support course sponsored by the American Medical Association.
ICS, incident command system.

medication including dexamethasone, aminophylline, furosemide, acetaminophen and antibiotics. Additional medication for plague was included due to a plague epidemic near the quake area in 2009.[10] While gradual ascent is the most effective prevention for altitude sickness, urgent situations only allow for pharmacological prophylactic measures.

*Rhodiola* is the most commonly used traditional Chinese medicine used to prevent altitude sickness and was recommended to each member of the Beijing EMS rescue team. Our data inconclusively showed that the incidence of AMS was not lower for team members who used *Rhodiola* versus those who did not take the herb. Further randomised controlled trials to assess the efficacy of herb medicine (such as *Ginkgo biloba*, *Rhodiola* and *Codonopsis*) are required to draw any firm conclusions.[11–14] Allopathic medications such as acetazolamide and dexamethasone are used to prevent altitude sickness.[14 15] Despite the availability of such prophylaxis, there is no effective means of preventing altitude sickness suitable to the rapid ascent and strenuous labour of plateau rescue work.

### High-altitude conditions adversely affect the rescue of disaster victims

In order to prevent effectively widespread trauma and secondary injuries, rescue workers need plateau-specific training before entering the field.[16] Medical professionals must pay special attention to wound-management and life support specific to high-altitude regions including:

(a) Physiological parameters for locals: haemoglobin concentration is higher for inhabitants of high-altitude regions than inhabitants of lowland regions. For high-altitude inhabitants, the concentration is higher for people from lowlands living in high-altitude regions than for locals.[17]
(b) Procedural differences due to low oxygen: $PaCO_2$ and $PaO_2$ values will also be lower than normal due to the low barometric pressure of high-altitude areas. Trauma and blood loss will be poorly tolerated due to lower oxygen pressure, with traumatic shock occurring earlier than lowland regions. Patients are at an increased risk of pulmonary oedema, heart failure and multiple organ dysfunction syndrome. Tourniquets for active bleeding must be carefully used and closely monitored in order to avoid deterioration of local tissue due to hypoxia.

### Plateau disasters raised unique challenges to the ICS

Incident command system (ICS) is crucial for delivering adequate and timely aid. An effective ICS is needed to manage the enormous influx of both rescue resources and rescue personnel. The 2004 Indian Ocean tsunami exposed issues with ICS, especially with the large amounts of rescue resources unable to access the affected area. The DISASTER paradigm (table 3) for plateau areas takes into account the geographic setting, local resources and local healthcare facilities for effective disaster management.

## LIMITATION

Several limitations existed in this study design and should be considered when generalising our findings to other populations or conditions. The primary limitation of our study is its relatively small sample size. The study was carried out in a homogenous population group, and most of them were healthy adult males. The use of *Rhodiola* to prevent AMS was not randomised since use was voluntary. Finally, AMS symptoms were self-reported through a questionnaire with the possibility of recall bias.

## SUMMARY

Given the unique conditions of high-altitude plateaus, it is unrealistic to mobilise rescue teams from lowlands for the initial rescue phase. It is more practical and efficient to mobilise local personnel who do not risk developing AMS. The 2010 Yushu earthquake demonstrated the need for a disaster response plan specific to each geographic region. If emergency personnel are to be mobilised for relief in high-altitude regions, further study is required to prevent altitude sickness among relief workers.

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**Competing interests** None.

**Patient consent** Written consent was obtained before the study began; original copies of consent forms are kept by the Beijing Emergency Medical Center.

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