Respiratory Rate within the First Hour of Ascent Predicts Subsequent Acute Mountain Sickness Severity

Sirous Jafarian MD*, Farzam Gorouhi MD*, Mohammad Ghergherechi MD**, Jamshid Lotfi MD*

Background: Altitude illness results from hypobaric hypoxia at altitudes higher than 2500 meters above sea level. To determine whether vital signs can be used as predictors for severe acute mountain sickness, we carried out a prospective observational study.

Methods: A cohort of 90 individuals (male/female ratio: 2: age: 13 – 65 years) in a mountain hotel’s clinic at 3450 meters in Iran were studied from September through October 2006. Demographics and vital signs were measured during the first hour of ascent. The individuals were followed for acute mountain sickness symptoms including headache, dizziness, nausea or vomiting, insomnia, and fatigue. Lake Louise criteria were used to diagnose acute mountain sickness. Severe acute mountain sickness was considered if a score of equal or more than 5 was present. Significance was assigned to values of $P<0.05$.

Results: Acute mountain sickness was diagnosed in 34 (37.8%) participants after 24 hours of ascent. Severe acute mountain sickness was detected in 14 (15.6%) participants. A respiratory rate of 20 or more during the first hour of ascent was recorded for nine (64.3%) patients with severe acute mountain sickness and 15 (19.7%) individuals in the negative/mild acute mountain sickness group. This suggests an association between early high respiratory rates and risk of subsequent severe acute mountain sickness ($P=0.001$).

Conclusion: There is an association between a rise in the respiratory rate and susceptibility to acute mountain sickness. This can enable us to predict severe acute mountain sickness and prevent it. Furthermore, Tochal Mountain Hotel guests should be aware of the risk of acute mountain sickness and should be recommended to use prophylactic acetazolamide or dexamethasone before ascent.

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Introduction

Altitude illness results from hypobaric hypoxia at altitudes higher than 2500 meters above sea level. The severity of acute mountain sickness (AMS), the most prevalent form of altitude illness, correlates with altitude and rate of ascent. Initial manifestations include headache, dizziness, nausea and vomiting, fatigue, and sleep difficulties.

Ascending too rapidly, overexertion within 24 hours of ascent, inadequate fluid intake, hypothermia, tobacco smoking, and consumption of alcohol or other sedatives can trigger and exacerbate AMS, while administration of 1 – 2 L/min oxygen will often relieve acute symptoms.

Physical fitness is not protective against high altitude illness. Common conditions such as hypertension, coronary artery disease (CAD), mild chronic obstructive pulmonary disease (COPD), diabetes, and pregnancy do not appear to affect the susceptibility to high altitude illness.

Severe AMS is a harmful situation which incapacitates individuals and might burden them...
with heavy costs. In the only previously published report from Iran, an overall AMS incidence of 60.8% was reported among Iranian mountaineers in Mount Damavand.\(^7\) We collected data to estimate the prevalence of AMS and severe AMS in an amateur population during their stay in a high altitude hotel. In addition, whether an ordinary individual will develop severe AMS within 24 hours after ascent is a serious question that we, as physicians in a mountain clinic at a high altitude of 3500 meters, are concerned with; especially that advanced clinical diagnostic tools and equipment are not generally available at such altitudes. We set out to determine which individual factors are associated with the severity of AMS and whether we can use simple physical examinations and early vital sign measures as predictors.

**Patients and Methods**

**Study setting and participants**

A prospective observational study was carried out on a cohort of 90 individuals over 12 years of age (range: 13 – 65) in Tochal Mountain Hotel’s Clinic, Tehran, Iran, from September through October 2006. Tochal Hotel, one of the highest hotels in the world, is located at an altitude of 3,500 meters above sea level and designed to host skiers, mountaineers, and ordinary people. The target population had been living at an altitude of 1,400 to 1,650 meters for at least one week before coming to the hotel and were transferred from a height of 1800 to 3500 meters using cable car within 45 – 60 minutes. The temperature was 20 – 27°C in different parts of the hotel during the days the study was conducted.

Age, gender, acclimatization, smoking habits, and past serious or chronic diseases were recorded. All guests with documented CAD, ischemic heart disease (IHD), cerebrovascular accident, COPD, asthma, and pregnancy were excluded (based on hotel’s rules). All participants gave oral consent and agreed not to drink alcohol, take sedatives, or use analgesics during their stay. Vital signs including pulse rate, respiratory rate, and blood pressure were measured by a general practitioner during the first hour of ascent after at least a 10-minute rest in supine position, and recorded as baseline measures.

According to the data by Dean et al.\(^8\) an estimated final AMS incidence of 40% and an alpha level of 5%, requires a sample size of 90 subjects for a 10% relative treatment effect. Five individuals were not admitted in the hotel because of documented history of CAD (2), IHD (1), COPD (1), and pregnancy (1). Thirteen others were excluded because they were under 12 years of age.

**Outcome assessment**

All participants were observed during the next 24 hours of ascent for AMS symptoms including headache, dizziness, gastrointestinal symptoms (anorexia, nausea, or vomiting), insomnia, and fatigue. Assessments were done by a single assessor. After 24 hours of ascent, a face to face interview was performed to determine if any individual had experienced AMS symptoms. AMS was diagnosed using Lake Louise criteria (score of equal or more than 3 with headache and at least one other symptom), which were set up by the Lake Louise consensus on the definition of altitude illness.\(^8\) Severe AMS was considered if both AMS and a score of 5 or more were present.

**Statistical analysis**

Data were entered into SPSS software version 13.0 (SPSS Inc, Chicago, USA). Using Chi-square test (Fisher’s exact test if appropriate), we analysed the association between categorical variables and the dichotomous variable of presence of severe AMS. In this case, all reported percentages are within the disease. To apply parametric tests dealing with continuous variables, we evaluated the normality of distributions using the one-sample Kolmogorov-Smirnov test. Independent sample t-test (Mann-Whitney U if appropriate) was used to determine any difference in the mean values between the two groups of AMS severity. Forward stepwise logistic regression analysis was performed for factors associated with the incidence and severity of AMS to calculate odds ratios. The results are reported as mean±one standard deviation (SD) and 95% confidence intervals (CI). Significance was assigned to values of \(P<0.05\).

**Results**

Of the 90 individuals, 30 (33.3%) were females and 60 (66.7%) were males. The mean age was 28.83±10.19 years (95% CI: 26.70 to 30.97). None of the participants experienced a standard acclimatization process. Twenty-eight (31.1%) were tobacco smokers. None of the participants gave a history of mountain sickness and no one
reported alcohol use during the 24 hours stay at Tochal Hotel. Furthermore, no prophylactic agent intake was reported by the participants in the 48 hours before ascent. Clinical examination ruled out any symptoms or signs of high altitude pulmonary edema, ataxia, or impaired consciousness (high altitude cerebral edema).

The mean systolic blood pressure was 108.45±15.35 mmHg (95% CI: 105.18 to 111.72) and the mean diastolic blood pressure was 69.30±9.71 mmHg (95% CI: 67.22 to 71.38). The mean rates of radial pulse and respiration were 87.73±16.74 (95% CI: 84.14 to 91.32) beats per minute (bpm) and 17.28±3.64 (95% CI: 16.50 to 18.08) breaths per minute (bpm), respectively. Seventy-four (82.2%) participants experienced at least one AMS-related symptom during their stay. AMS diagnosis was made in 34 (37.8%) participants after 24 hours of ascent. Severe AMS was detected in 14 (15.6%) participants. Table 1 shows the prevalence of each AMS symptom and their severity.

Age, gender, smoking habits, baseline blood pressure, and baseline pulse rate were not associated with AMS severity. Baseline respiratory rate was less than 20 bpm in 61 (71.8%) individuals, whereas 24 (28.2%) had a respiratory rate of 20 bpm or more. Of the patients with severe AMS, nine (64.3%) had a baseline respiratory rate of 20 bpm or more, while 15 (19.7%) individuals in the negative/mild AMS group (AMS score ≤ 4) ventilated with a similar rate; this indicated an association between a high baseline respiratory rate and a higher risk of severe AMS (P=0.001). Moreover, an odds ratio of 8.5 (95% CI: 2.3 to 31.6) was calculated for a baseline respiratory rate over 20 bpm as a predisposing factor to severe AMS (R square=0.22, P=0.001). Table 2 and Table 3 show demographics and baseline vital signs in patients with AMS and severe AMS, respectively.

### Discussion

Up to 37.8% of nonprofessional individuals whose baseline and subsequent signs and symptoms were recorded experienced AMS within 24 hours of ascent. Insomnia and headache were the most prevalent symptoms among patients; a finding consistent with prior studies.\(^9\)\(^-\)\(^{11}\)

Honigman and colleagues\(^1\)\(^1\) have carried out the largest AMS survey in adults (n=3158) to date, and they demonstrated that 25% of the visitors traveling to moderate heights (2500 to 3000 meters) developed AMS. The participants of the present study dealt with an almost rapid ascent and higher altitude. An AMS prevalence of 37.8% and severe AMS prevalence of 15.6% is similar to previous reports from 3000 to 4000 meters altitudes.\(^8\)\(^-\)\(^{11}\)

To the best of our knowledge, there is no report showing a direct association between early increased respiratory rates and the occurrence of AMS. Erba et al.\(^1\)\(^2\) showed that ascending from 3560 to 4559 meters was associated with an

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**Table 1. Frequencies of AMS symptoms and their severity (n=90).**

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Negative</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>40 (44.4%)</td>
<td>26 (28.9%)</td>
<td>17 (18.9%)</td>
<td>7 (7.8%)</td>
</tr>
<tr>
<td>Dizziness</td>
<td>72 (80.0%)</td>
<td>15 (16.7%)</td>
<td>3 (3.3%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Gastrointestinal symptoms</td>
<td>66 (73.3%)</td>
<td>18 (20.0%)</td>
<td>3 (3.3%)</td>
<td>3 (3.3%)</td>
</tr>
<tr>
<td>Fatigue</td>
<td>74 (82.2%)</td>
<td>12 (13.3%)</td>
<td>3 (3.3%)</td>
<td>1 (1.1%)</td>
</tr>
<tr>
<td>Insomnia</td>
<td>37 (41.1%)</td>
<td>23 (25.6%)</td>
<td>22 (24.4%)</td>
<td>8 (9.9%)</td>
</tr>
</tbody>
</table>

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**Table 2. Demographics and first hour vital signs in patients with AMS compared to participants without AMS.**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Patients with AMS *</th>
<th>95% CI</th>
<th>AMS-negative participants*</th>
<th>95% CI</th>
<th>P value**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>32.29 (10.95)</td>
<td>28.47–36.15</td>
<td>26.73 (9.17)</td>
<td>24.28–29.19</td>
<td>0.01</td>
</tr>
<tr>
<td>Female</td>
<td>16 (47.1%)</td>
<td>—</td>
<td>14 (25.0%)</td>
<td>—</td>
<td>0.03</td>
</tr>
<tr>
<td>Cigarette smoker</td>
<td>7 (20.6%)</td>
<td>—</td>
<td>16 (29.1%)</td>
<td>—</td>
<td>0.37</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>108.94 (14.18)</td>
<td>103.91–113.97</td>
<td>108.15 (16.14)</td>
<td>103.74–112.55</td>
<td>0.81</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>70.00 (17.50)</td>
<td>64.71–72.26</td>
<td>70.00 (17.50)</td>
<td>67.29–72.33</td>
<td>0.62</td>
</tr>
<tr>
<td>Heart rate/min</td>
<td>80.00 (25.00)</td>
<td>84.31–96.90</td>
<td>80.00 (15.00)</td>
<td>81.53–90.35</td>
<td>0.26</td>
</tr>
<tr>
<td>Respiratory rate/min</td>
<td>17.94 (4.21)</td>
<td>16.42–19.46</td>
<td>16.89 (3.23)</td>
<td>16.00–17.78</td>
<td>0.23</td>
</tr>
</tbody>
</table>

\*Quantities are means (SD) (median [IQR] if appropriate) and frequencies are the numbers (%); **P values to compare means were computed by using independent t-test (Mann-Whitney U test if appropriate). Chi-square (Fisher’s exact if appropriate) test was considered for dichotomous data.
increase in ventilation, mainly related to an increase in tidal volume, whereas breath rate changed little. The increase in ventilation was more pronounced in the AMS group than in the controls, and was only significant in the former. Accordingly, the AMS group showed a significant increase in the mean inspiratory flow, a measure of respiratory rate and susceptibility to AMS. This can enable us to predict severe AMS and prevent it. Furthermore, Tochal Mountain Hotel guests should be aware of the risk of AMS and should be recommended to use prophylactic agents including 750 mg/d acetazolamide, 8 mg/d dexamethasone, or etc. before ascent.

According to our findings, there is a significant association between respiratory rate in the first hour of an individual’s ascent to high altitudes and developing severe AMS, which seriously affects regular function and sleep. In our experience, it is possible to predict severe AMS in the following 24 hours of ascent using a cut point of 20 respirations per minute, when oxymetry or more complex devices are not easy to access. Because hypoxia is the main contributor to high altitude illness, association between respiratory rate and susceptibility to AMS was not unpredictable. Atmospheric pressure and the partial pressure of oxygen decrease rapidly at increasing levels above the earth’s surface. Hypoxic stimulation of peripheral chemoreceptors leads to the respiratory response to altitude that consists of hyperventilation and dyspnea as a consequence.

The responsible mechanisms for dyspnea have not been fully clarified. Theories suggest that input into the CNS from some peripheral afferent receptors and/or central pathway that stimulate pulmonary receptors might explain the hypobaric hypoxic dyspnea. Hypoxia and rapid respiration result in hypocapnia and respiratory alkalosis with a variety of symptoms and discomforts, which explain the headache, dizziness, and nausea in patients with AMS. An increased respiratory rate appears to be one of the first alarms of individual adjustment failure to high altitude. On the other hand, later respiratory rate assessment might mislead physicians because alkalemia, theoretically, can depress ventilatory drive.

In conclusion, our findings showed an association between an early increase in respiratory rate and susceptibility to AMS. This can enable us to predict the severe AMS and prevent it. Furthermore, Tochal Mountain Hotel guests should be aware of the risk of AMS and should be recommended to use prophylactic agents including 750 mg/d acetazolamide, 8 mg/d dexamethasone, or etc. before ascent.

### References


### Table 3. Demographics and first hour vital signs in patients with severe AMS compared to participants with negative/mild AMS.

<table>
<thead>
<tr>
<th></th>
<th>Severe AMS patients*</th>
<th>95% CI</th>
<th>Negative/Mild AMS participants*</th>
<th>95% CI</th>
<th>P value**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>32.14 (11.09)</td>
<td>25.74–38.54</td>
<td>28.22 (9.97)</td>
<td>25.94–30.50</td>
<td>0.19</td>
</tr>
<tr>
<td>Female</td>
<td>6 (42.9)</td>
<td>—</td>
<td>24 (31.6)</td>
<td>—</td>
<td>0.54</td>
</tr>
<tr>
<td>Cigarette smoker</td>
<td>2 (14.3)</td>
<td>—</td>
<td>21 (28.0)</td>
<td>—</td>
<td>0.51</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>111.15 (15.57)</td>
<td>101.75–120.56</td>
<td>107.97 (15.37)</td>
<td>104.41–111.53</td>
<td>0.49</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>70.00 (20.00)</td>
<td>63.69–77.08</td>
<td>70.00 (15.00)</td>
<td>66.89–71.33</td>
<td>0.82</td>
</tr>
<tr>
<td>Heart rate /min</td>
<td>80.00 (35.00)</td>
<td>77.94–100.53</td>
<td>85.00 (22.50)</td>
<td>83.62–91.32</td>
<td>0.91</td>
</tr>
<tr>
<td>Respiratory rate /min</td>
<td>20.85 (3.18)</td>
<td>18.92–22.77</td>
<td>16.64 (3.35)</td>
<td>15.85–17.43</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Quantities are means (SD) (median (IQR) if appropriate) and frequencies are numbers (%); **P values to compare means were computed by using independent t-test (Mann-Whitney U test if appropriate). Chi-square (Fisher’s exact if appropriate) test was considered for dichotomous data.

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