Obesity is a risk factor for acute mountain sickness: a prospective study in Tibet railway construction workers on Tibetan plateau

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Abstract. – OBJECTIVE: Although few retrospective studies of high altitude have reported that obesity might be associated with the development of acute mountain sickness (AMS), this association has not been fully studied prospectively. The aim of this study was to investigate the effect of obesity on subjects with acute high-altitude exposure.

PATIENTS AND METHODS: Totally 262 male subjects aged 25-43 (mean 33.2 ± 9.3) years with acute high-altitude exposure were involved in this study. Among them, there are 120 obese and 142 non-obese young-middle aged male subjects. Each subject completed an AMS (acute mountain sickness) self-report questionnaire at sea level and after ascending high-altitude (3658 meters) 12 hours and 24 hours. Weight and height were measured and BMI was calculated. Vital capacity of lungs was measured. Venous blood was sampled for measuring hemoglobin at baseline. Arterial blood was taken for evaluating arterial oxygen saturation (SO_2), arterial oxygen pressure (PaO_2) and arterial carbon dioxide pressure ($PaCO_2$) at baseline and 24 hours after ascending high-altitude.

RESULTS: No statistical differences were found between groups at age ($p = 0.1488$), hemoglobin ($p = 0.5807$) and vital capacity ($p = 0.1806$). BMI in the two groups was significantly different ($p < 0.001$) because it is the cut-off point of grouping. At sea level, no statistical differences were found between groups at SO2 ($p = 0.1806$), PaO_2 ($p = 0.0949$), $PaCO_2$ ($p = 0.1960$). But 24 hours after ascending high-altitude, SO_2 ($p = 0.0002$), PaO_2 ($p < 0.001$) were much lower and $PaCO_2$ ($p < 0.001$) was significantly higher in obese group than in non-obese group. Comparison of AMS score: No symptom was reported at sea level in all participants (scored 0). But 12-hour and 24-hour after ascending high-altitude, the AMS scores in obese group were significantly higher than those in non-obese group ($p < 0.001$).

CONCLUSIONS: Obesity is an important risk factor in the development of acute mountain sickness.

Key words:
Acute mountain sickness, Obesity, Risk factor, Tibetan plateau.

Introduction

An increasing number of persons who live at low altitude, rapid exposed to high altitude for work, leisure, or sport. Rapid ascending to high-altitude often causes acute mountain sickness (AMS), a syndrome characterized by headache, dizziness, fatigue, poor appetite, nausea, insomnia. The prevalence and severity of AMS depend on the speed of ascent, the altitude attained, different seasons, age, sex, exertion levels while at altitude and the ventilatory response to acute hypoxia[1,2]. AMS is not only uncomfortable, it may progress to high-altitude cerebral edema (HACE) in some persons. Onset is heralded by worsening symptoms of AMS, progressing to ataxia and eventually to coma and death if not treated. High-altitude pulmonary edema (HAPE) is uncommon, but is the leading cause of altitude illness-related death. It may appear in otherwise healthy persons and may progress rapidly with cough, dyspnea, and frothy sputum[3]. Few retrospective study reported that obesity might be associated with AMS[4-6]. Unfortunately, this association has not been fully studied prospectively at high-altitude in healthy obese subjects. The hypothesis in this study was that obese subjects are more likely to develop AMS than non-obese subjects during acute exposure to high-altitude (Lhasa, 3658 meters) in Tibet.

Patients and Methods

Subjects

The Human Ethics Committee of our institute approved the research protocols in accordance with international agreements (Helsinki Declaration[7] of 1975, revised 2008). All participants obtained written informed consent. The study population were recruited from workers who built Tibet Railway. According to criteria of Chinese

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Working Group on Obesity[8], obesity was defined as a BMI of 28 kg/m² or greater. Non-obesity was defined as a BMI of 18.5-23.9 kg/m². All workers are male subjects. All participants resided at sea level (0 m) in He-bei province in China. No one had ever been to high-altitude before. All of them went to high-altitude rapidly by air within 5 hours. Totally 120 obese men (mean age 34.1 ± 8.7 years) and 142 non-obese men (mean age 31.8 ± 9.3 years) fit in the criteria mentioned above. All data and follow-up were done in Tibet General Hospital.

Study Protocol

This is a prospective randomized clinical trial.

According to guidelines established by the Lake Louise AMS consensus report[9], each subject completed an AMS self-report questionnaire at sea level and after ascending high-altitude 12 hours and 24 hours. The items in the questionnaire included symptoms of headache, gastrointestinal symptoms, fatigue or weakness, dizziness of lightheadedness, and insomnia. The questionnaire uses a scale of 0-3 indicating nil, mild, moderate and severe, the minimum score is 0, and the maximal score is 15. The presence of AMS was defined as presence of headache and a cumulative score ≥3. Severity of AMS was defined as: 0 to 2 points = no AMS, 3 to 4 points = mild AMS, 5 or more = severe AMS.

Clinical study: weight and height were measured while the subjects were fasting and wearing only underwear. Weight was measured to the nearest 0.1 kg, height to the nearest 0.1 cm. BMI (body mass index) was measured as the ratio between weight and the square of the height. Vital capacity of lungs was measured at baseline.

Laboratory test: venous blood was sampled for measuring hemoglobin at baseline. Arterial blood was taken for evaluating arterial oxygen saturation (SO_2), arterial oxygen pressure (PaO_2) and arterial carbon dioxide pressure ($PaCO_2$) at baseline and 24 hours after ascending high-altitude. SO_2, PaO_2, $PaCO_2$ were measured with Novametrix blood gas analyst (USA).

Statistical Analysis

All analyses were carried out with Stata 7.0 software system. Data were expressed as mean ± standard deviation (SD). Analysis of variance (ANOVA) and Student's t test was used to evaluate the measurement data. Chi square statistic (Pearson x^2) was used to compare count data. Statistical significance was inferred at $p < 0.05$.

Results

Subjects

As shown in Table I, no statistical differences were found between groups at age, hemoglobin and vital capacity ($p > 0.05$). BMI in the two groups was significantly different because it is the cut-off point of grouping.

Comparison of AMS Score

No symptom was reported at sea level in all participants (scored 0). But 12-hour and 24-hour after ascending high-altitude, the AMS scores in obese group were significantly higher than those in non-obese group (Table II) ($p < 0.001$).

Comparison of Blood Gas Analysis

At sea level, no statistical differences were found between groups at SO_2, PaO_2, and $PaCO_2$ (Tables II, IV and V). But 24 hours after ascending high-altitude, SO_2, PaO_2 were much lower and $PaCO_2$ was significantly higher in obese group than in non-obese group ($p < 0.001$).

Discussion

Obesity, which is characterized by an abnormally large adipose tissue mass, leads to the development of various pathophysiologic disorders (especially cardiovascular and respiratory abnormalities) and a decrease in life expectancy[10]. Obesity-related respiratory dysfunctions put obese individuals at risk at high-altitude[11]. Thus, increases the possibility of acute high-altitude exposure difficulties for obese subject during recreational and working activities[3,12]. Obstructive sleep apnea (OSA) is a condition that affects 1%-4% of the general population and 25%-35% of obese individuals. OSA is well known to be associated with hypoxia and hypoventilation, which is one of the possible reasons that make obese subjects vulnerable to acute high-altitude exposure[13].

The connection between obesity and AMS is not clear. Some studies suggest no relationship between AMS and BMI[14]. However, this may be partly explained by the relative paucity of overweight or obese subjects in these studies. The present study found that there was a positive effect of a high BMI on the incidence of AMS. The principal finding in this study was that obese subjects have higher AMS scores than non-obese subjects during 24-hour high-altitude exposure at 3658 meters above sea levels. In this study, AMS scores in-

Table I. General characteristics of participants at baseline.

	Non-obese (n = 142)	Obese (n = 120)	*t* value	*p* value
Age (years)	31.8±9.3	34.1±8.7	1.4524	0.1488
BMI (kg/m²)	22.7±2.9	29.9±3.8	12.2861	< 0.001
Hemoglobin (g/L)	141.7±17.1	143.3±15.7	0.5538	0.5807
Vital Capacity (L)	5.9±0.8	5.7±0.9	1.3462	0.1806

Table II. Comparison of AMS score.

	Non-obese (n = 142)	Obese (n = 120)	*t* value	*p* value
Baseline	0	0	NS	NS
12-hour	1.2±0.9	1.9±1.1	4.0059	0.0001
24-hour	2.8±2.3	4.3±2.5	3.5737	0.0005

NS: no significant

Table III. Comparison of arterial oxygen saturation (SO_2 %).

	Non-obese (n = 142)	Obese (n = 120)	*t* value	*p* value
Baseline	98.5±0.8	98.3±0.9	1.3462	0.1806
24-hour	85.2±4.6	81.9±5.3	3.8152	0.0002

Table IV. Comparison of partial pressure of oxygen (PaO_2 mmHg).

	Non-obese (n = 142)	Obese (n = 120)	*t* value	*p* value
Baseline	98.4±1.5	97.9±1.9	1.6825	0.0949
24-hour	90.1±2.3	87.8±2.7	5.2655	< 0.001

Table V. Comparison of partial pressure of carbon dioxide ($PaCO_2$ mmHg).

	Non-obese (n = 142)	Obese (n = 120)	*t* value	*p* value
Baseline	33.6±2.1	33.1±2.3	1.2997	0.1960
24-hour	36.7±2.9	39.1±3.1	4.5725	< 0.001

creased with time during high-altitude exposure in both non-obese and obese subjects. This demonstrated that AMS symptoms are common during 24-hour of rapid ascending to such a high-altitude as 3658 meters. Similarly, blood gas analysis in all subjects deteriorated after ascending high-altitude. All the parameters mentioned above in obese group were worse than those in non-obese group. The severity of symptoms was significantly different between obese and non-obese subjects, which indicated that the occurrence of AMS may be closely related to increased body weight. This was consistent with results from other studies that found a significant high incidence of AMS among individuals with higher BMI[15]. We conclude that obesity remains a possible risk factor for AMS.

AMS frequently occurs in subjects who rapid ascending on altitude beyond 3000 m without acclimatizing. The incidence and severity of AMS depend on the speed of ascending, the altitude attained and susceptibility of subjects. According to data in this study, obesity is another risk factor for rapid ascending high-altitude. The outcome of this study was consistent with another respective study[16].

It is not clear how obesity predisposes an individual to AMS. Presumably, an overweight or obese subject is more frequently associated with hypoventilation, sleep apnea, and increased oxygen consumption[17-19], thus rendering themselves vulnerable to AMS at high altitude. Also, recent study[20] indicated that there is a multitude of responses to cellular hypoxia due to genetic changes.

We would like to underline that there are some limitations in this study. First, in order to make the baseline characteristics of study populations consistent, we selected male young-middle aged subjects from the same province to be representatives. But it is not clear to what extent these findings can be extrapolated to the general public, including women, children and elderly people.

Second, only vital capacity (VC) of lungs was measured to be representative of pulmonary function because of limitation of experiment condition. Of course, VC cannot fully describe pulmonary function.

Conclusions

Obesity is an important risk factor in the development of acute mountain sickness. In this study, obese men were more vulnerable to AMS. We suggest that the obese subjects should fully prepared before go to altitude, especially circulatory and respiratory functions should be evaluated.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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