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

Akut yüksek irtifa hastalığının risk faktörü olarak obezite: Tibet platosunda Tibet demiryolu işçileri ile ilgili bir prospektif çalışma

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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 may progress to high-altitude cerebral edema (HACE) and high-altitude pulmonary edema (HAPE), which are the leading cause of altitude illness-related death. Few retrospective study reported that obesity might be associated with AMS (3, 4). 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 m) in Tibet.

The Human Ethics Committee of our institute approved the research protocols in accordance with international agreements (Helsinki Declaration of 1975, revised 2008) (5). The study population were recruited from workers who built Tibet Railway. According to criteria of Chinese Working Group on Obesity, obesity was defined as a BMI of 28 kg/m^2 or greater. Non-obesity was defined as a BMI of 18.5-23.9 kg/m^2. All participants resided at sea level (0 m) in He-bei province in China. 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.

This is a prospective observational study.

According to guidelines established by the Lake Louise AMS consensus report (6), each subject completed an AMS self-report questionnaire at sea level and after ascending high-altitude 12 hours and 24 hours. 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.

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 study: 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.

Statistical analysis: All analyses were carried out with Stata 7.0 software system. Data were expressed as mean±standard deviation. 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 $p<0.05$.

Subjects: As shown in Table 1, no statistical differences were found between groups at age, hemoglobin and vital capacity ($p>0.05$).

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Accepted Date/Kabul Tarihi: 04.06.2013 **Available Online Date/Çevrimiçi Yayın Tarihi:** 25.11.2013

doi:10.5152/akd.2013.4585

Comparison of AMS score (Table 2). 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).

Comparison of blood gas analysis (Table 3-5). At sea level, no statistical differences were found between groups at SO_2, PaO_2, $PaCO_2$. 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).

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 (7). Obesity-related respiratory dysfunctions put obese individuals at risk at high-altitude. Thus increases the possibility of acute high-altitude exposure difficulties for obese subject during recreational and working activities (8).

The connection between obesity and AMS is not clear. Some studies suggest no relationship between AMS and BMI. 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 m above sea levels. The severity of symptoms was significantly different between obese and non-obese subjects, which indicated that the occurrence of AMS might be closely related to increased body weight.

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.

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 (9, 10), thus rendering themselves vulnerable to AMS at high altitude. In conclusion, obesity is an important risk factor in the development of acute mountain sickness.

Conflict of interest: None declared

Peer-review: Externally peer-reviewed

Authorship contributions: Concept - B.Y.; Design - M.L.; Supervision - Z.J.S.; Resource - B.Y.; Materials - B.C.; Data collection&/or Processing - X.L.; Analysis &/or interpretation - X.L.; Literature search - Y.D.C.; Writing - B.Y.; Critical review - Y.D.C.; Other - Z.J.S.

Acknowledgement

This work was supported by Beijing Nova Program (No. 2008B55, Bo YANG) from Beijing Municipal Science, Beijing Natural Science Foundation (7132227, Bo YANG), Technology Commission, and VB Foundation (09010500205, Bo YANG) from Chinese Medical Association, and Chinese PLA Twelfth Five-year Plan for Medical Sciences (No.CWS12J130, Xin LI).

Table 1. General characteristics of participants at baseline

	Non-obese (n=142)	Obese (n=120)	*t	*p
Age, years	31.8±9.3	34.1±8.7	1.4524	0.1488
BMI, kg/m^2	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

Data are presented as mean±SD
*t-test for independent samples
BMI - body mass index

Table 2. Comparison of AMS score

	Non-obese (n=142)	Obese (n=120)	*t	*p
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

Data are presented as mean±SD
*t-test for independent samples
AMS - acute mountain thickness
NS - no significant

Table 3. Comparison of arterial oxygen saturation (SO_2,%)

	Non-obese (n=142)	Obese (n=120)	*t	*p
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

Data are presented as mean±SD
*t-test for independent samples

Table 4. Comparison of partial pressure of oxygen (PaO_2, mm Hg)

	Non-obese (n=142)	Obese (n=120)	*t	*p
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

Data are presented as mean±SD
*t-test for independent samples

Table 5. Comparison of partial pressure of carbon dioxide ($PaCO_2$, mm Hg)

	Non-obese (n=142)	Obese (n=120)	*t	*p
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

Data are presented as mean±SD
*t-test for independent samples

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