

Assessment of Acute Mountain Sickness: How to integrate the advantages of the Lake Louise Score and the Chinese AMS Score

Yu Wu

Army Medical University

Peng Li (✉ lipengtmmu@163.com)

Army Military Medical University <https://orcid.org/0000-0002-3902-8102>

Zhifeng Zhong

Army Medical University

Jiixin Xie

Army Medical University

Simin Zhou

Army Medical University

Yuqi Gao

Army Medical University

Jian Chen

Army Medical University

Research

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Abstract

Aims: To compare the differences in acute mountain sickness (AMS) incidence between two AMS diagnostic scoring criteria, including the Lake Louise Score and the Chinese AMS Score.

Methods: A total of 2486 young men completed questionnaires after flying from Chendu (500 m) to Lasha (3658 m). The AMS incidence was investigated using a questionnaire that contained the scoring criteria for the LLS and CAS. To determine the grouping of all the symptoms on the AMS questionnaire, a systematic cluster analysis and two-step cluster analysis were used to analyse various symptoms and cases separately.

Results: The AMS incidence was 37.5% (n = 932) according to the LLS, in which the cut-off point depended on headache and a total score ≥ 3 , and 59.3% (n = 1473) according to the CAS, in which the cut-off point depended on headache, vomiting or a total score ≥ 5 . The LLS and CAS outcomes had a significant positive correlation (Spearman's $\rho = 0.918$, $P < 0.05$) and were moderately consistent (kappa value = 0.488, $P < 0.001$). The positive AMS incidence determined by the CAS was significantly higher than that by the LLS ($P < 0.001$). Compared with the LLS, the sensitivity was 100%, the specificity was 65.23%, the positive predictive value was 63.34%, and the negative predictive value was 100% for the CAS in the diagnosis of AMS. The CAS identified all AMS subjects diagnosed by the LLS, and an additional 541 subjects. Of all the symptoms investigated, the dominant symptoms were fatigue (59.3%), dizziness (55.0%), headache (50.6%), chest tightness (40.4%), and shortness of breath (37.2%), and the last two symptoms were not included in the LLS. The cluster analysis show that chest distress, shortness of breath and palpitations were relatively independent of the major symptoms assessed by the LLS.

Conclusion: The CAS had testing characteristics for diagnosing AMS similar to those of the Lake Louise Questionnaire Score, and the CAS diagnosed a higher prevalence of AMS than the LLS. It is suggested that chest distress and shortness of breath should be paid adequate attention and taken into account in AMS diagnostic criteria in the next revision to better diagnosis and study AMS.

Background

Acute mountain sickness (AMS) refers to a series of clinical syndrome that occur when people ascend to a plateau > 2500 m above sea level from a plain or from a plateau to a higher altitude over a short period of time[1]. These symptoms usually manifest as headache, dizziness, nausea, anorexia, fatigue, and sleep disturbances, and they often occur within a few hours (6–12 h) after reaching the plateau. Although AMS is often a self-limiting disease and these symptoms can resolve spontaneously after 3 to 7 days without treatment in most cases, AMS may progress to life-threatening high-altitude cerebral edema (HACE)[2] or high-altitude pulmonary edema (HAPE) in fewer than 1% of patients. AMS remains a common consequence of rapid ascent. Globally, the incidence of AMS differs greatly in different reports (varying from 10 to 80%)[3, 4]. The incidence is closely related to the ascent rate, altitude attained, season, individual predisposition, including physiology, psychology and genetic susceptibility, and specific behaviours and activities[5], including activity level at high altitude and medical prophylaxis, which influence the development of AMS [6, 7]. In addition, quantification of the prevalence and severity of AMS varies according to the diagnostic criteria used to establish a diagnosis of AMS.[8, 9].

At present, the diagnosis of AMS does not have reliable, clinical physiological indicators as diagnostic markers[10]. Its diagnosis relies only on individual self-assessment of the intensity of symptoms using a variety of diagnostic criteria [11]. With the development of high-altitude disease research, various altitude sickness scoring systems have been applied to the diagnosis of acute mountain diseases, such as the Hackett clinical score[12], the Environmental Symptoms Questionnaire (ESQ)[13], the AMS-Cerebral score (AMS-C), the clinical functional score (CFS), the visual analog scale (VAS)[4, 14], the Lake Louise Score (LLS) [15], and the Chinese AMS Score (CAS) [16]. These diagnostic scales can be divided into self-assessment questionnaires of symptoms and clinician assessment scales. The Hackett AMS score is a scoring system consisting of a structured interview that mainly investigates altitude-related headaches, nausea and five other symptoms. Physical examination emphasizes periorbital or peripheral oedema, respiratory rate, pulmonary rales and ataxia[12]. The ESQ-IV was introduced by the US military in the late 1970s and early 1980s to obtain information on the incidence and severity of symptoms following exposure to different climatic conditions, including acute altitude exposure, and contained 52–67 items spanning a wider range of environmental reactions[13, 17–19]. The AMS-C and LLS were derived from the initial Environmental Symptoms Questionnaire score. The VAS is mainly used to identify the severity of symptoms and evaluate AMS; it is the most recent tool to be used for evaluating AMS [4, 14]. The LLS is currently an internationally recognized, useful research tool for diagnosing AMS[11]. The LLS assesses five symptoms (headache, dizziness, fatigue, gastrointestinal reactions, and difficulty sleeping) of AMS using a 4-point Likert scale[15]. Due to the simplicity and reliability of the LLS, it is widely used in clinical diagnosis and scientific research. However, it still has some shortcomings and needs constant improvement. An international consensus was presented that made some adjustments to the LLS, including eliminating disturbed sleep as a questionnaire item in 2018[20].

China has a large plateau area and the largest AMS patient population in the world. Some scholars and doctors often use the Chinese AMS Score (CAS) to diagnose AMS in China. The CAS was published in the Third Chinese National Symposium on High Altitude Medicine of the Chinese Medical Association in September 1995[16, 21]. In contrast to the LLS, which emphasizes the importance of headaches as a primary criterion for diagnosing AMS, the CAS stipulates that headache and vomiting are non-obligatory symptoms that may indicate AMS; the CAS indicates that patients with no headache can also be diagnosed with AMS when other symptoms are very serious[22]. The CAS includes a series of symptoms not mentioned in the LLS: dizziness, nausea, palpitation, shortness of breath, chest distress, blurred vision, insomnia, lethargy, anorexia, abdominal distension, diarrhoea, constipation, lip cyanosis, and numbness of the extremities (Table 1). In previous studies, some scholars compared the difference between the two AMS scoring systems [8, 9] found that the CAS outcomes were in good agreement with the LLS outcomes and provided a more positive diagnosis. However, how these two scoring systems perform relative to one another has not been studied in detail, and the sample sizes of the previous studies were small.

Therefore, we compared the relative performance of the Chinese AMS Score against what is commonly considered a reference standard, i.e., the Lake Louise Score, using 3 to indicate a positive test result. We analysed a group of 2486 subjects who flew from Chengdu (500 m) to Lhasa (3658 m) and studied the

relationship between the LLS and CAS diagnostic criteria for AMS to explore whether the limited symptoms of the LLS could cover the actual state of AMS well in a large sample population and whether the CAS including more symptoms is useful for improving the LLS.

Methods

1 Subjects

We enrolled 2503 participants at 500 m, 17 of whom were excluded for incomplete data. Thus, we analysed data obtained from the remaining 2486 subjects. Participants were required to have abstained from tobacco and alcohol for the previous 6 months, and other disease factors were excluded. The participants were all healthy young men (average age 18.33 ± 1.23 years, range 16 to 24 years) and lived below 2500 m altitude; no subject had a medical or AMS history. In December 2012, the subjects were transported by plane for almost two and a half hours from Chengdu (500 m) to Lhasa in Tibet (3658 m). Before entering the plateau, the subjects underwent high-altitude health education and unified preventive measures but did not take preventive drugs. After arriving on the plateau, the individuals with serious symptoms were treated with drugs after a doctor's diagnosis. This study was approved by the Ethics Committee of the Army Military Medical University.

2 Questionnaires And Scoring Systems

We designed a questionnaire that included all the detailed symptoms covered by the LLS and CAS. Headache, gastrointestinal symptoms, fatigue and/or weakness, dizziness/lightheadedness, and sleep disturbance were each assigned a grade of 0 to 3 points. The remaining symptoms, i.e., palpitations, shortness of breath, chest distress, dazzling/blurred vision, anorexia, abdominal distension, diarrhoea, constipation, cyanosis of the lips, and numbness of the extremities, were recorded as 0 or 1 point. The questionnaire also collected demographic information on the subjects: age, ethnicity, individual history of AMS, smoker or non-smoker status, and permanent residence.

At 9 o'clock in the morning on the second day after arrival on the plateau, a questionnaire was issued by 5 trained investigators. AMS symptom scores were evaluated according to the LLS and CAS.

2.1 The Lake Louise Scoring system

The LLS examines five symptoms: headache, gastrointestinal symptoms, fatigue/weakness, dizziness/light-headedness, and difficulty sleeping. Each symptom was divided into none (score of 0), mild (1), moderate (2), and severe (3) (Table 1). The presence of headache plus a cumulative score of 3 or greater is usually considered positive for AMS. Mild AMS was considered 3–5 points, and moderate or severe AMS was considered a score of 6 or greater (Table 2). Although the LLS was adjusted in 2018 to remove sleep disturbance as a questionnaire item[20], considering the consistency and coherence of the research, we still used the old version of the LLS here.

2.2 The Chinese AMS Scoring system

The standard CAS examines headache, vomiting, palpitation, short breath, vertigo, insomnia, drowsiness, decreased food appetite, abdominal distension, diarrhoea, constipation, lip cyanosis, hand and foot numbness and other symptoms. Headache and nausea/vomiting were divided into four grades, corresponding to 1, 2, 4, and 7 points, and other symptoms were recorded as 0 or 1 point each (Table 1). According to the total CAS outcome, AMS was divided into 4 degrees: essentially no reaction (total score < 5 points), mild reaction [headache (+) or vomiting (+) or total score of 5 to 10 points], moderate reaction (headache (++) or vomiting (++) or total score between 10 and 15 points] and severe reaction [headache (+++) or vomiting (+++) or total score ≥ 16] (Table 2). A mild reaction was considered to be positive for AMS[16, 21].

Table 1
Summary of the Lake Louise Score (LLS) and Chinese Acute Mountain Sickness Score (CAS)

LLS ^a		CAS ^b		
Symptom	Detailed description	Score	Detailed description	Score
Headache	No headache	0	No headache, no suffering expression, no effect on daily activity.	1
Headache	Mild headache	1	Mild headache with suffering expression; obvious improvement of headache after taking regular analgesic medicine; no effect on daily activity.	2
	Moderate headache	2	Moderate headache with suffering expression; slight improvement of headache after taking regular analgesic medicine; daily activity is affected.	4
	Severe headache, incapacitating	3	Severe and unbearable headache; in bed and unable to get up; no effect of regular analgesic medication.	7
Gastrointestinal	None	0	None	0
Gastrointestinal symptoms	Poor appetite or nausea	1	Vomiting 1 to 2 times/d, which does not interfere with daily activities.	2
	Moderate nausea &/or vomiting	2	Vomiting 3 to 4 times/d, which interferes with daily activities.	4
	Severe nausea &/or vomiting	3	Vomiting more than 3 times/d; patients confined to bed and no relief after medication.	7
			Nausea, anorexia, abdominal distension, diarrhea, constipation	1 point each
Fatigue	Not tired or weak	0		
Fatigue &/or weakness	Mild fatigue/ weakness	1		
	Moderate fatigue/ weakness	2		
	Fatigue &/or weakness	3		
	Severe fatigue/ weakness			
Neurological	Not dizzy	0	Dizziness/light-headedness	1 point each
Dizziness/light-headedness	Mild dizziness	1	Dazzling or blurred vision	
	Moderate dizziness	2	Numbness of the extremities	
	Severe dizziness, incapacitating	3		
Sleep	Slept as well as usual	0	Insomnia	1 point each
Difficulty sleeping	Did not sleep as well as usual	1	Lethargy	
	Woke many times, poor sleep	2		
	Difficulty sleeping	3		
	Could not sleep at all			
Respiratory/ circulatory system			Palpitation, Shortness of breath, Chest distress, Cyanosis of the lips	

a. Score requires the presence of headache (the other criteria do not) and at least 1 other symptom to establish an AMS diagnosis. A score of 3 or more indicates AMS.

b. Presence of headache, vomiting, or a total score of 5 indicates AMS.

Table 2
Assessment of the cut-off value and severity for the LLS and CAS

	LLS	CAS
Diagnostic criteria	Headache, at least one other symptom, total score ≥ 3	Headache or vomiting or total score ≥ 5
Cut-off value	Total score ≥ 3	Total score ≥ 5
Degree		
Absent (\pm)	0–2	1–4
Mild (+)	3–5	Headache +, or vomiting +; or total score of 5–10
Moderate (++)	6 or more	Headache ++, or vomiting ++; or total score of 11–15
Severe (+++)		Headache +++, or vomiting+++; or total score of ≥ 16

3 Statistical Analysis

Statistical analysis was performed using PASW Statistics 20 software (IBM Corp., Armonk, NY). The numeration data are expressed in terms of the frequency, and the Spearman correlation analysis, the Kappa consistency test and paired χ^2 test (McNemar's test) were used for comparisons of the two scoring criteria. The Bonferroni-corrected chi-square method was used for comparisons between groups. Cluster analysis of symptoms was based on systematic cluster analysis. The cluster method was an inter-group link, and the measurement standard was Pearson correlation with 1 correlation coefficient as the distance between symptoms. Case clustering was performed with two-step clustering, and the log-likelihood was used to measure the distance. The clustering judgement was based on the Bayesian information criterion (BIC). All tests were two-tailed, and a P -value < 0.05 was considered significant.

Results

1. The incidence of AMS determined by the two scoring systems

In all 2486 subjects, the incidence of AMS was 37.5% ($n = 932$) using the LLS and 59.3% using the CAS ($n = 1473$). There was a significant positive correlation between the LLS and CAS outcomes (Spearman's $\rho = 0.918$, $P < 0.05$) (Fig. 1). The diagnostic results of the CAS and LLS were generally consistent, and the kappa value in the chi-square test was 0.488 ($P < 0.001$). The results of McNemar's test showed that there was a difference in the diagnosis between the two scoring standards. The positive rate of CAS-determined AMS was significantly higher than that of LLS-determined AMS ($\chi = 565.61$, $P = 0.000$).

Both the CAS and LLS were evaluated by symptomatology scoring in a similar way. However, due to the different symptoms and weights assigned (Table 1, Table 2), the incidence determined by the CAS assessment was higher than that by the LLS (59.3% vs 37.5%). The CAS had diagnostic accuracy for moderate and severe AMS similar to that of the LLS (16.9% vs 17.2%). However, the difference was significant for mild AMS (42.3% vs 20.3%) (Fig. 2).

2. Diagnostic Accuracy Of The Cas

As the current mainstream standard for AMS diagnosis, validated by LLS diagnoses of AMS, the AUC was 0.820 (0.804–0.837; $P < 0.01$), indicating that the CAS was an accurately verified means of determining AMS diagnoses. The Youden index was 0.652. Taking the LLS as a reference, the sensitivity, specificity, positive predictive value and negative predictive value of the CAS for the diagnosis of AMS were 100%, 65.18%, 63.20%, and 100%, respectively.

3. Dominant symptoms

We found that the five dominant symptoms in all subjects were fatigue (59.3%), dizziness (55.0%), headache (50.6%), chest tightness (40.4%), and shortness of breath (37.2%) (Fig. 3, Table 3). Among them, chest tightness and shortness of breath were from the CAS scoring system and were not mentioned in the LLS system.

Ratio: The frequency of the symptoms/total number

Table 3
Most frequent symptoms of AMS (N = 2486)

	Absent (0)	Mild (1)	Moderate (2)	Severe (3)
Fatigue	1012(40.7%)	1106(44.5%)	325(13.1)	43(1.7%)
Dizziness	1118(45%)	1107(44.5%)	238(9.6%)	23(0.9%)
Headache	1227(49.4%)	918(36.9%)	289(11.6%)	52(2.1%)
Chest tightness*	1481(59.6%)	1005(40.4%)		
Shortness of breath*	1562(62.8%)	924(37.2%)		
LLS Score	Absent (0–2)	Mild (3–5)	Severe (≥ 6)	
	1554(62.5%)	505(20.3%)	427(17.2%)	
CAS Score	Absent (1–4)	Mild (5–10)	Moderate (11–15)	Severe (≥ 16)
	1013(40.7%)	1051(42.3%)	349(14.0%)	73(2.9%)
*From the Chinese AMS scoring system, 0 points for absent, 1 point for symptomatic				

All the symptoms on the AMS questionnaire were analysed by correlation based on whether they appeared at the same time and were clustered by systematic cluster analysis. The results showed that the distance between 6 symptoms, such as blurred vision and 5 variables from the LLS, was far. Because of its low frequency in the population, it could not be considered a main symptom of AMS. The distance between 3 symptoms, such as palpitation, chest distress and shortness of breath, was small, and the symptoms were relatively independent. Taking a height of 0.72 as the point of penetration, the symptoms can be divided into two modules: (1) headache, dizziness, fatigue, difficulty sleeping, vomiting and anorexia, which are basically consistent with the 5 categories of the LLS, and (2) shortness of breath, palpitations, and chest tightness. The incidence of these symptoms was high in the population, and they are relatively independent of the classic LLS symptoms. The LLS scoring system cannot express the occurrence of these symptoms, so they should be regarded as important symptoms of AMS and were combined into 1 category at height = 0.86. (Fig. 4).

AMS symptoms cluster analysis based on systematic cluster analysis. The cluster method was an inter-group link, and the measurement standard was Pearson correlation with 1-correlation coefficient as the distance between symptoms.

4. Main Symptoms Of Lls Negative And Cas Positive

We found that all subjects diagnosed with AMS by the LLS (n = 932) were also positive for AMS according to the CAS. However, a total of 541 subjects were judged AMS positive by the CAS and AMS negative by the LLS. Among them, the CAS identified 523 as mild, 14 as moderate and 4 as severe. No severe mountain sickness, such as acute pulmonary oedema or acute brain oedema, occurred. The symptoms with the highest incidence were headache in 327 (60.6%), dizziness in 280 (51.9%), chest distress in 256 (47.3%), fatigue in 252 (46.6%), shortness of breath in 243 (44.9%), cyclosis of the lips in 189 (34.8%) and palpitations in 169 (31.1%) (Fig. 5). Chest distress, shortness of breath and so on led to the higher total CAS score of this part of the population, which met the CAS diagnostic criteria for AMS, but these symptoms were not included in the LLS, which led to the totally different results of 541 people using the two scoring systems.

The 541 cases were clustered using two-step clustering. After pre-clustering, six symptoms were considered less important variables (abdominal distention, diarrhoea, constipation, cyanosis of the lips, blurred vision, numbness of the extremities) and were deleted, and the remaining nine symptoms were used for two-step clustering again to obtain two clusters. Category 1 included 214 people (39.6%) without headache but with fatigue, dizziness, palpitations, chest distress, shortness of breath, and 327 people (60.4%) with headache and no other symptoms were included in Category 2. The distribution of clustering symptoms is shown in Fig. 3a, and the comparison of clustering symptoms is shown in Fig. 3b.

In addition, we found that there were no headaches (with a score of 0) in the four subjects who were identified as having severe AMS but that there were very serious gastroenteric symptoms, with a score of 3. At the same time, 3 people had fatigue/weakness, and 3 people had difficulty sleeping. According to the CAS standards, there were also some people with shortness of breath, chest distress, dazzling/blurred vision, cyanosis of the lips, numbness of the extremities and other symptoms. Their total LLS score was greater than 5.

Table 4
Symptom distribution and scores of 4 subjects with severe AMS according to the CAS in 541.

	Headache	Gastrointestinal symptoms	Fatigue/ weakness	Dizziness/ lightheadedness	Difficulty sleeping	Shortness of breath	Chest distress	Dazzling/blurred vision	Cyanosis of the lips	Numbness of the extremities
Case 1	0	3	3	1	0	1	0	1	0	0
Case 2	0	3	2	2	1	1	0	1	0	1
Case 3	0	3	1	1	1	1	1	0	1	0
Case 4	0	3	2	0	1	0	1	1	1	1

Discussion

This study compared the outcomes of two scoring criteria (the Lake Louise Score (LLS; score of ≥ 3) and the Chinese AMS Score (CAS; score of ≥ 5) on the assessment of AMS in a large group including a total of 2486 subjects who rapidly entered a high-altitude area (3658 m) by plane. To the best of our knowledge, this is the first large-sample study on the incidence of AMS as determined by the LLS and CAS diagnostic criteria. The CAS had testing characteristics for diagnosing AMS similar to those of the LLS and showed a generally consistent trend with the LLS, and the CAS diagnosed a higher prevalence of AMS than the LLS criteria did.

The results of this study show that the incidence of AMS diagnosed by the LLS and CAS was 37.5% and 59.3%, respectively. In studies that used an airplane approach, Harrison et al.[23] reported an AMS incidence of 33.3% using the LLS criteria, and Ren et al.[24] reported an AMS incidence of 57.2% using the standard CAS; our results are consistent with both of theirs. Because AMS evaluation lacks reliable biomarkers and clinical indicators, it mainly depends on the determination of some neurological, gastrointestinal and respiratory symptoms at high altitude. Both the CAS and LLS were evaluated by symptomatology scoring in a similar way. However, due to the different symptoms and weights assigned, the incidence determined by the CAS assessment was higher than that by the LLS (59.3% vs 37.5%). This was consistent with previous studies[8, 9]. The CAS had diagnostic accuracy for moderate and severe AMS similar to those of the LLS (16.9% vs 17.2%). However, the difference was significant for mild AMS (42.3% vs 20.3%).

To help improve the AMS diagnostic criteria, some scholars compared and evaluated the different scoring criteria. [25] [26] [27] [11] Some Chinese scholars have studied the difference between the LLS and CAS in defining AMS. Chen et al.[9] surveyed 339 males residing at sea level who travelled by train and car to 3200 m. Wu et al.[8] surveyed 58 males who went by train and recorded the AMS incidence when they reached different altitude sites, ending at 3658 m. They found that CAS outcomes were in good agreement with LLS outcomes and can accurately diagnose AMS, suggesting that combining the LLS and the CAS in applications of clinical diagnosis can more objectively diagnose AMS than one scoring system alone.

The LLS and CAS are self-report questionnaires that diagnose AMS using a subject's self-assessment of symptom intensity. The two scoring criteria have different scoring rules, resulting in different diagnostic results[20]. The LLS highlights the importance of headache as the main criterion for the diagnosis of AMS and demands the presence of headache, and a total score of 3 or more can diagnose AMS. It is generally believed that acute mountain sickness is associated with high-altitude cerebral oedema and that this pathophysiological process should be explored. It is believed that the vasodilation caused by hypoxia or its effectors may cause headache by activating the trigeminovascular system[28]. An alternative hypothesis is that early AMS is caused by mild high-altitude cerebral oedema[29]. AMS is the pathogenetic precursor to high-altitude cerebral oedema.

However, there are ongoing controversies about whether headache is a necessary criterion for the diagnosis of AMS[22, 30]. The CAS criteria mainly emphasize headache and vomiting, which are major but nonspecific symptoms in the diagnosis of AMS, and the weight of headache is still very high. According to the severity, whether a symptom affects activity ability and general drug treatment response, weight scores of 1, 2, 4, and 7 are given. Even if subjects do not have headache or vomiting but merely have a total score of 5 or more, they could also be diagnosed with AMS. In this study, 541 subjects were diagnosed with AMS by the CAS, while they were diagnosed as AMS negative by the LLS. Although they had mild AMS as determined by the CAS and may not have progressed to life-threatening pulmonary and cerebral oedema, these people were still troubled by many typical symptoms (such as headache, vomiting, chest tightness, shortness of breath, etc.). Because there was no headache (214, 39.6%) or only headache and the total score of less than 3 (327, 60.4%), AMS could not be diagnosed by the LLS. For example, four subjects with severe gastrointestinal symptoms were diagnosed with severe AMS by the CAS but were considered to not have AMS by the LLS due to no headache. This observation is in line with a new view of AMS: AMS might not be a single syndrome but may manifest in different ways and present as symptom clusters that vary between patients, such as headache, headache and sleep disorders, fatigue and respiratory symptoms, and gastrointestinal symptom clusters[5, 31]. Therefore, whether headache should be a necessary item in the diagnosis of AMS and the difference in pathophysiological mechanisms between atypical manifestations without headache and typical AMS need further research and discussion. If we want to improve the AMS diagnostic criteria to achieve the desired diagnostic ability, we should consider a small number of people who have no headache but have more overall discomfort. It is beneficial for medical interventions to define them as AMS patients.

The LLS includes five independently assessed symptoms, while the CAS includes more than ten other types of symptoms, such as palpitation, chest tightness and shortness of breath, which are scored as 0 or 1 point. It is simpler to use the LLS to make diagnoses on the plateau, as it is conducive to rapidly diagnose patients. The CAS diagnostic criteria are more extensive but also increase the complexity of diagnosis. For example, the CAS takes into account the judgement-biasing effect of conventional drugs, while the LLS depends only on the subjective feelings of the participants. The additional symptoms included

in the CAS can help medical staff to find more unadaptable people in time and to initiate appropriate treatment to alleviate the further development of symptoms.

The influence of high altitude on organisms involves nearly every organ system. However, the LLS did not include the symptoms of the effects of hypoxia on the respiratory system because scholars considered the primary significance of AMS to be its potential for progression to HACE.[32] However, high-altitude pulmonary edema (HAPE) is also a high-altitude illness with an incidence rate of approximately 0.1%. HAPE that is ignored or unrecognized may pass rapidly through a stage of dyspnoea and progress overnight to severe encephalopathy and coma[32]. According to the survey results, the incidence of chest distress was 40.4%, ranking fourth among symptoms, and the incidence of shortness of breath was 37.2%, ranking fifth among symptoms, both of which are symptoms of the influence of a hypoxic environment on the respiratory system. The cluster analysis results also confirmed this point; shortness of breath and chest distress were relatively independent of the five symptoms on the LLS. Therefore, it is suggested that the two symptoms involved in the CAS should be included in the scoring system in future revisions of the standard. This helps AMS diagnostic instruments identify more potential patients and provide timely medical services to improve the living comfort and mobility of patients. The AMS diagnostic criteria have been continuously improving[20]. To better diagnosis and study AMS, we hope that our research can provide some help for the improvement of AMS scoring criteria.

Although this study had a large sample size, the participants were all young men, preventing generalizations from our sample to women and other age groups. The monitoring index was simple, as it only analysed and compared the main indexes and scores for AMS, but physiological indexes, such as pulse, blood pressure or blood oxygen saturation, were not recorded.

Conclusion

The CAS is a widely used diagnostic standard for AMS in China. Headache is considered a major but nonspecific symptom in the diagnosis of AMS, and the CAS also contains 15 other symptoms. In our study, the CAS had testing characteristics for diagnosing AMS similar to those of the LLS and showed a generally consistent trend with the LLS. The CAS diagnosed a higher prevalence of AMS than the LLS at 3658 m when travelled to by aircraft. Chest distress and shortness of breath are high frequency symptoms of AMS. It is suggested that they should be included in the scoring system in the next revision to better diagnosis and study AMS.

Abbreviations

AMS: Acute mountain sickness; LLS: Lake Louise Score; CAS: Chinese AMS Score; HACE: High-altitude cerebral edema; HAPE: High-altitude pulmonary edema; ESQ : Environmental Symptoms Questionnaire ; AMS-C: AMS-Cerebral score; CFS: Clinical functional score; VAS: Visual analog scale; BIC: Bayesian information criterion. BIC :Bayesian information criterion;

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Third Military Medical University. We attached the informed consent to the questionnaire, and all participants written the informed consent before filling in the questionnaire. Ethical issues have been fully considered in the research process to protect the rights of participants.

Consent for publication

Not Applicable.

Availability of data and materials

The datasets are available from the corresponding author on reasonable request.

Competing Interest

The authors declare that they have no competing interests.

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Authors' contributions

YG and JC participated in the design of this study. YW and JC performed the experiment. YW ,ZZ and PL performed the data processing and statistical analysis. YW drafted the manuscript and PL, JX, SZ revised the manuscript. All authors read and agreed to its content and approved the final manuscript.

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Figures

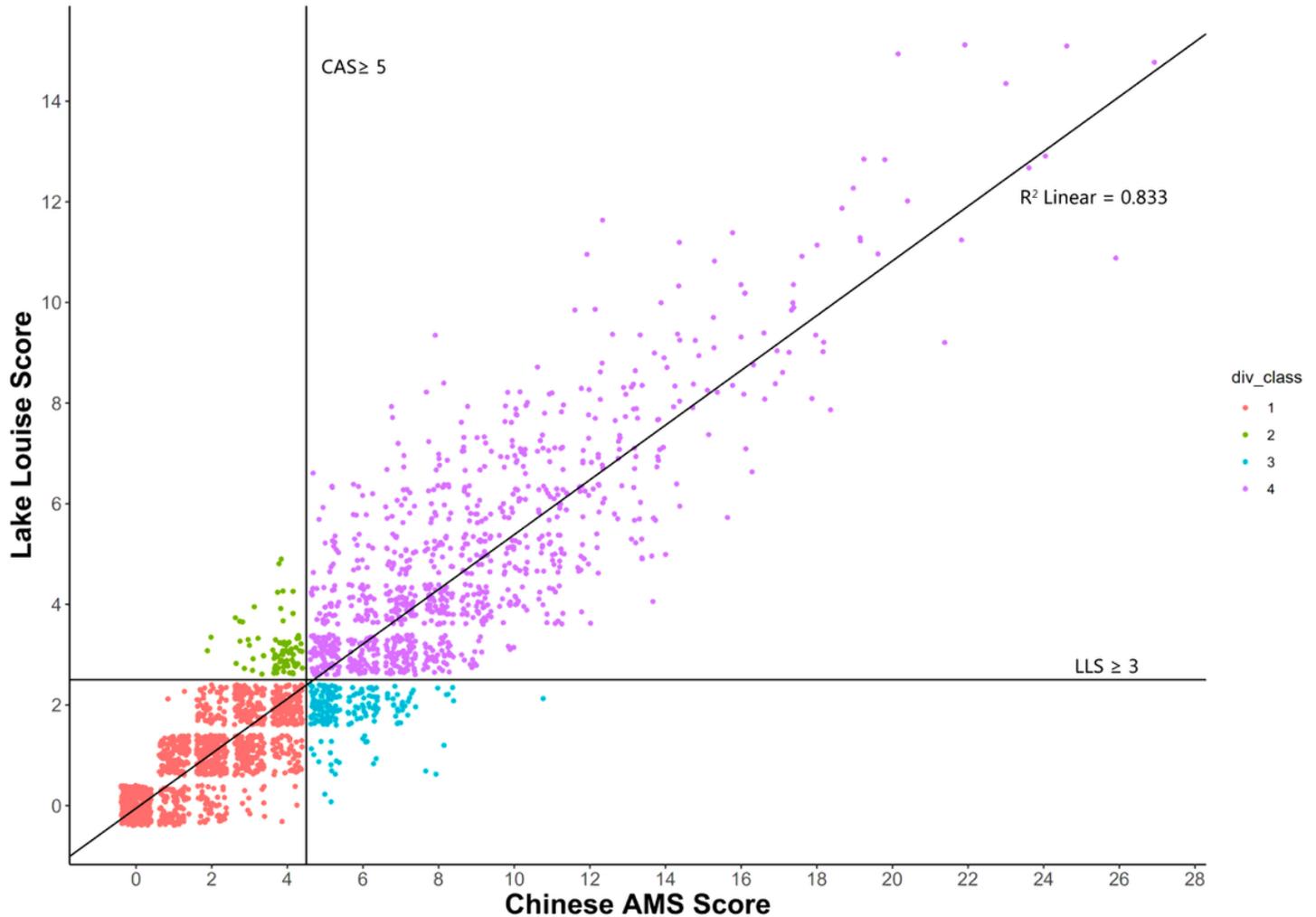


Figure 1
 Correlation between the Lake Louise Score (LLS) and the Chinese AMS Score (CAS) at 3680 m. The black solid line is the overall fit line, and the solid points represent the CAS and LLS scores of each subject, with $R^2 \text{ linear} = 0.833$ and Spearman's $\rho = 0.918$, $P < 0.05$.

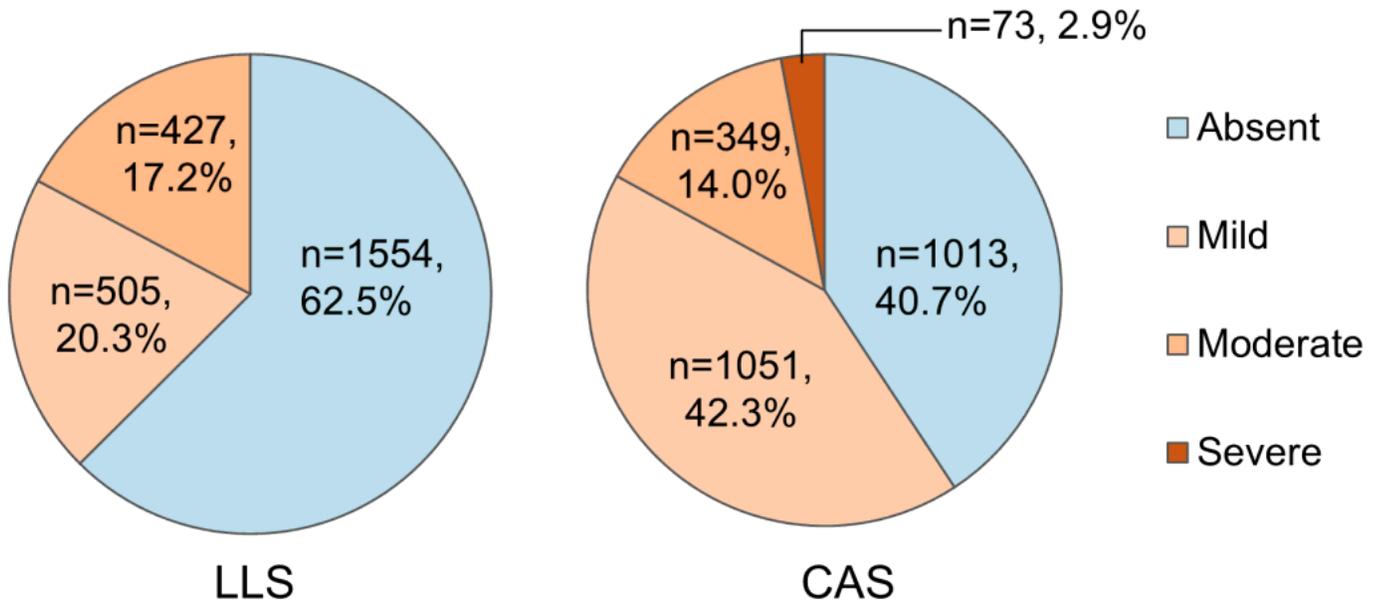


Figure 2

Results for the degree of acute mountain sickness according to the Lake Louise Score (LLS) and the Chinese AMS Score (CAS)

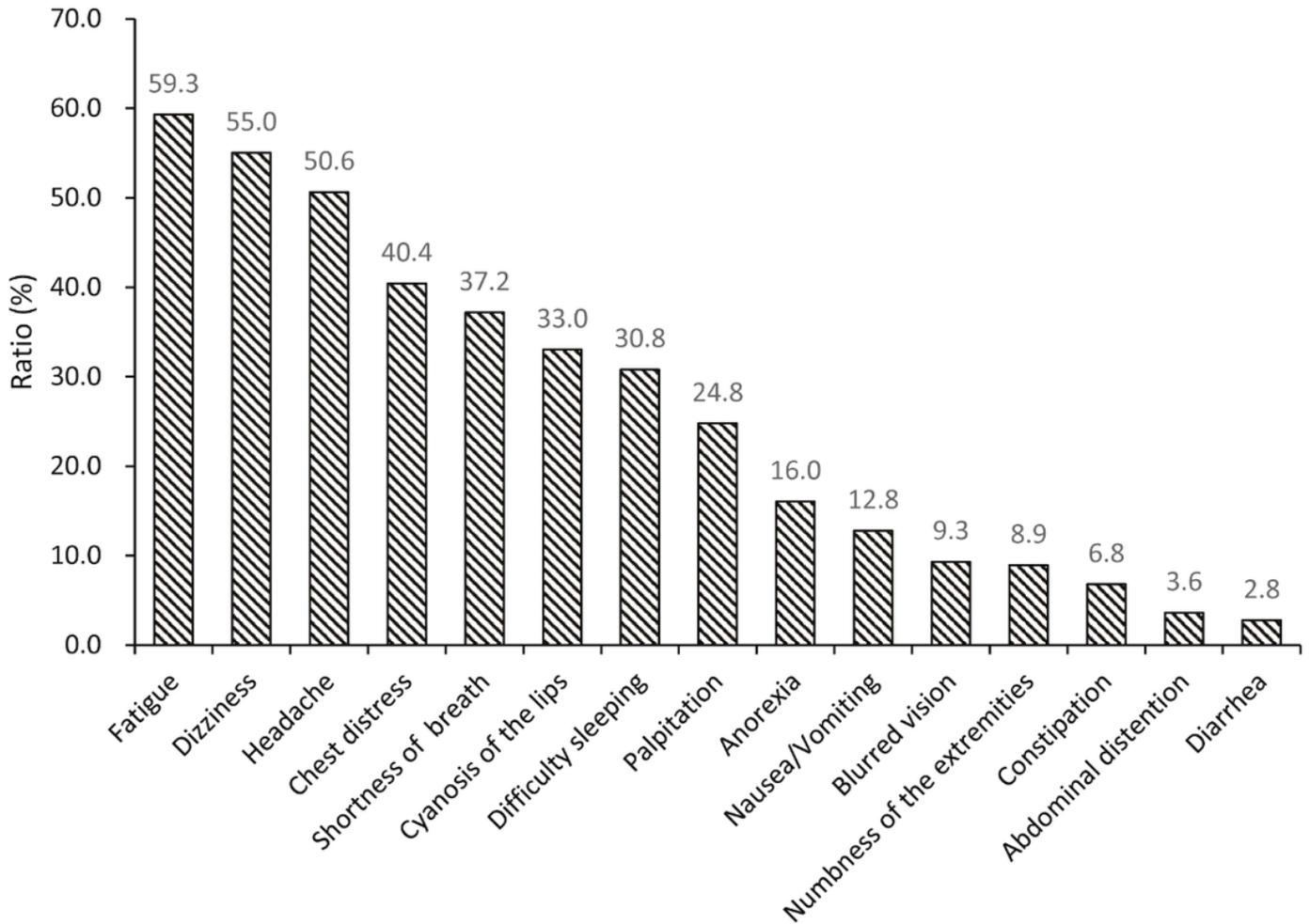


Figure 3

Difference in the positive rate of symptoms in the population.

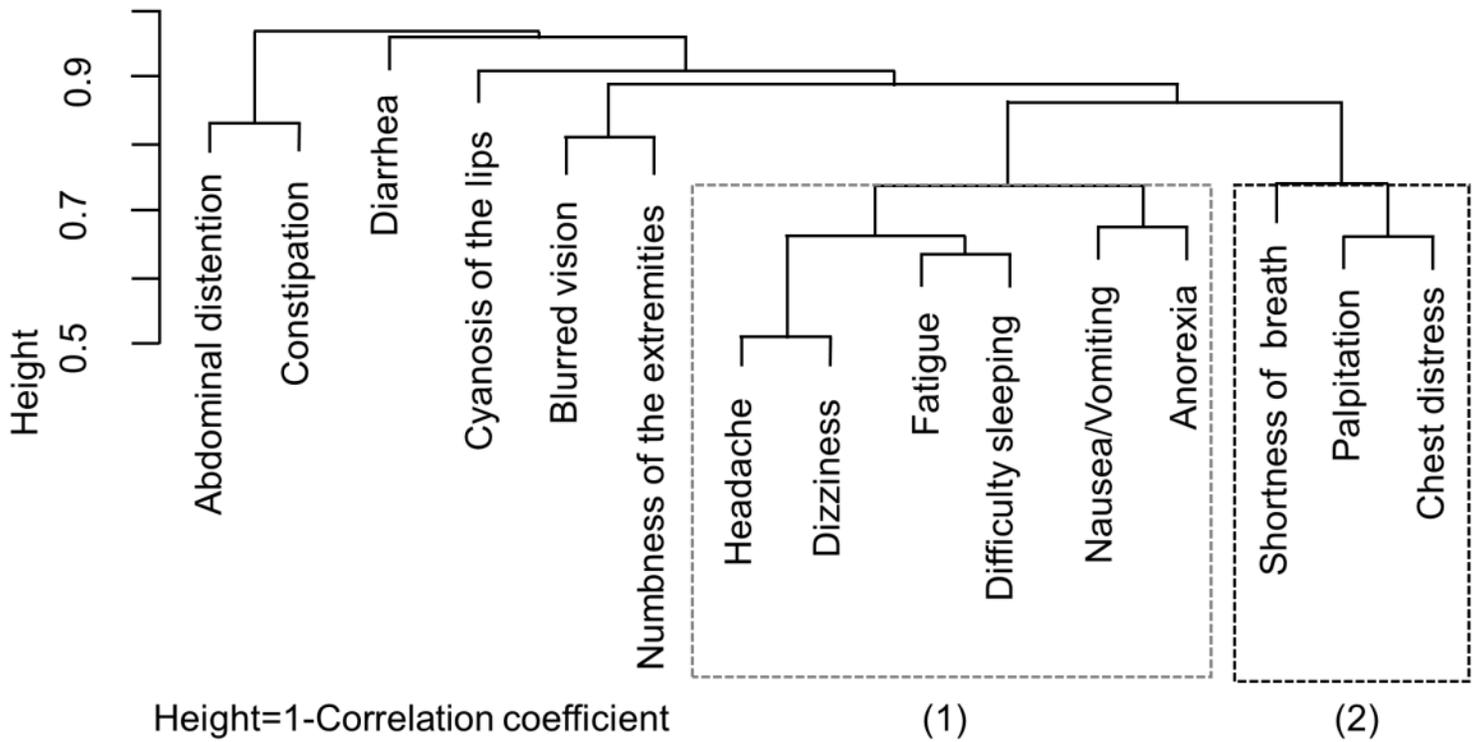


Figure 4

AMS symptom cluster dendrogram.

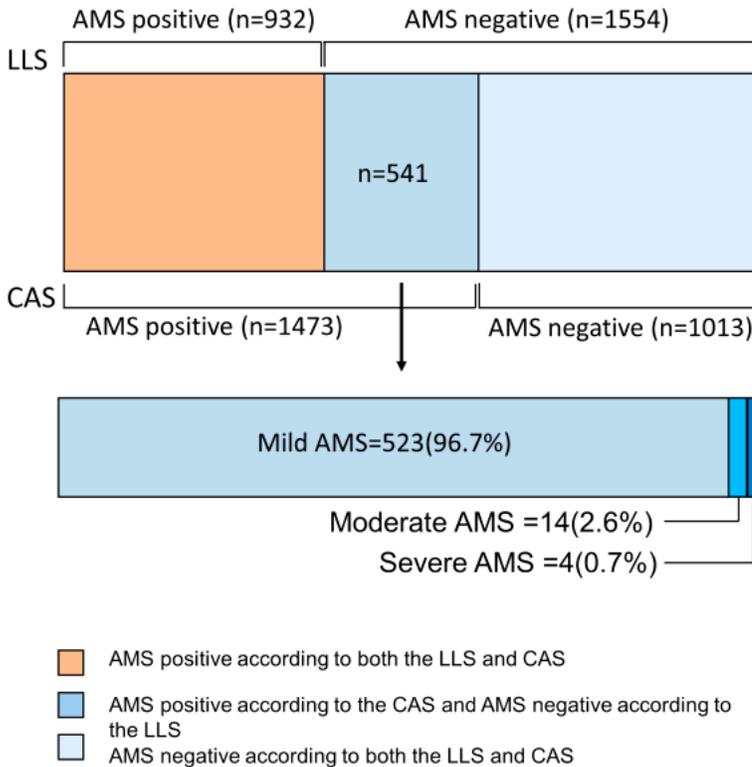


Figure 5

Main characteristics of 541 AMS-positive subjects according to the CAS and AMS-negative subjects according to the LLS

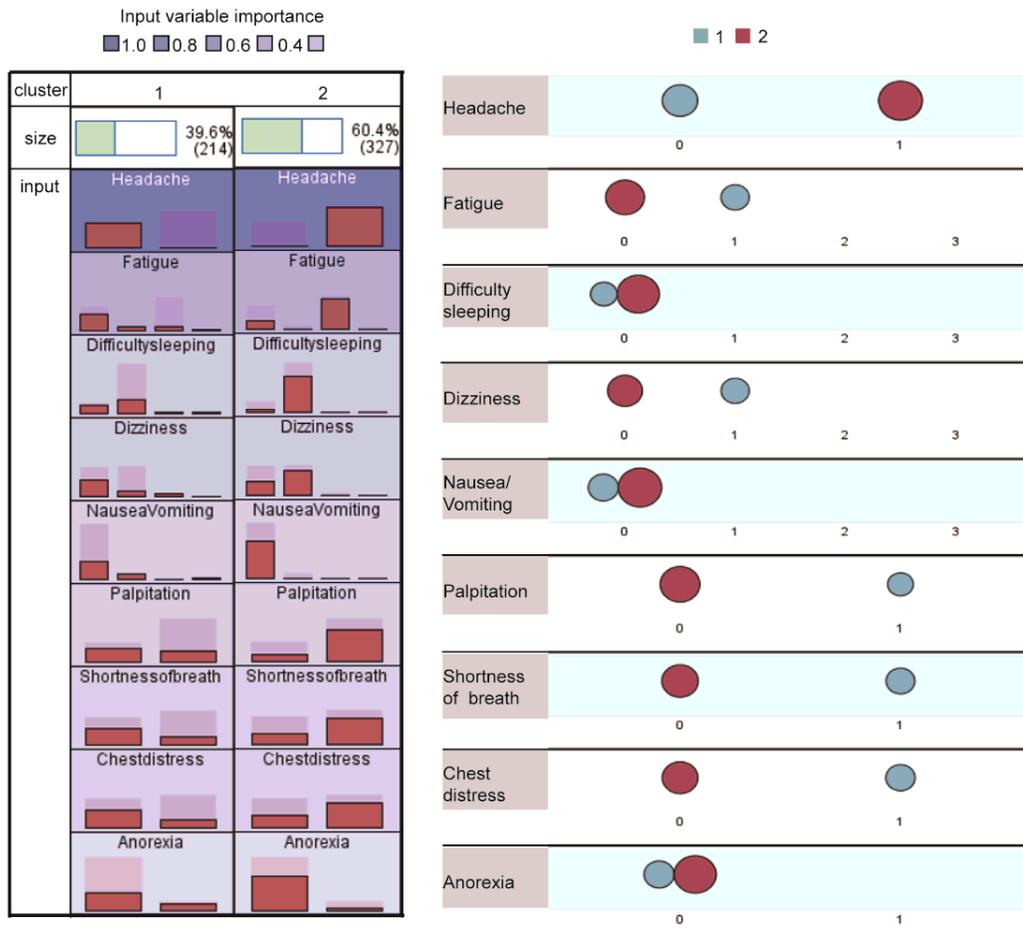


Figure 6

The distribution and comparison of clustered symptoms using two-step clustering