

Different physiopsychological changes between AMS-susceptible and AMS-resistant pre-selected Antarctic expeditioners in Tibet

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Abstract Through dynamically monitoring changes of acute mountain sickness (AMS) occurrences, cardiopulmonary function and mood states from Shanghai (4 m) to Lhasa (3650 m) and Yambajan (4300 m), Tibet, we obtained physiopsychological data of the 37th Chinese Antarctic pre-selected expeditioners for Kunlun Station. Through analyzing different physiopsychological changes between AMS-susceptible (AMS-S) and AMS-resistant (AMS-R) expeditioners, we would explore indicators to screen hypoxia-susceptible expeditioners. According to AMS occurrences evaluated by Lake Louise Score (LLS) in Yambajan, we divided the expeditioners ($n=24$, 31.92 ± 5.76 a) into AMS-S and AMS-R groups. Using a series of medical instruments and questionnaires, we monitored their cardiopulmonary function and mood states, and analyzed the differences of physiopsychological parameters between AMS-S and AMS-R groups. Compared with Shanghai, when expeditioners arrived in Yambajan, in both AMS-S and AMS-R groups, oxygen saturation (SpO_2) significantly decreased, and blood pressure significantly increased ($P<0.05$). As for electrocardiogram (ECG), interval from the beginning to the end of QRS complex wave (QRS), interval from the beginning of QRS complex wave to the end of T wave (QT), interval between 2 adjacent P waves (PP) and interval between 2 adjacent R waves (RR) significantly decreased, heart rate (HR) and HR-corrected QT interval (QTc) significantly increased ($P<0.05$). Cardiac contractility and pumping function significantly decreased, systemic vascular resistance significantly increased ($P<0.05$). Pulmonary airway patency significantly increased ($P<0.05$). Compared with AMS-R group, AMS-S group showed significantly lower SpO_2 and higher stroke volume variation (SVV) in Shanghai, however, significantly lower maximal expiratory flow at 75% of forced vital capacity (MEF₇₅), higher levels of anxiety, fatigue and confusion in Yambajan ($P<0.05$). In conclusion, when expeditioners arrived at 4300 m, their cardiopulmonary function and mood states changed significantly. SpO_2 , SVV, MEF₇₅, anxiety, fatigue and confusion maybe could be used as clues for screening hypoxia-susceptible individuals.

Keywords Antarctic, pre-selected expeditioner, hypoxia, Tibet, acute mountain sickness, cardiovascular function, pulmonary function, mood

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1 Introduction

When sea-level residents quickly enter elevations above 2500 m, they are susceptible to acute mountain sickness (AMS). Common symptoms of AMS are insomnia, fatigue, palpitation, headache, dizziness, cyanosis, nausea and loss of appetite (Singh et al., 1969; Hackett and Roach, 2001). But individual resistance to hypoxia is different, and current researches on hypoxia resistance and susceptibility are not completely clear. There are no specific methods for screening people susceptible to hypoxia directly. Therefore, we took the occurrence of AMS as an important indicator to judge the susceptibility to hypoxia. Through exposing people living at low altitude areas acutely to high-altitude environment, we evaluated their AMS occurrences. Furthermore, we compared the physiopsychological differences between the hypoxia-resistant and hypoxia-susceptible people, and tried to find some physiopsychological indicators in those susceptible to hypoxia.

Chinese Antarctic Kunlun Station (80°25'S, 77°6'E, 4087 m) is located in Dome A, the highest point on the Antarctic ice sheet, which is considered one of the most challenging environments on Earth. Kunlun Station has hypobaric hypoxia, extremely cold, strong wind, strong solar radiation in summer and other extreme environmental factors. The most challenging factor for expeditioners is hypoxia. To guarantee the life security of expeditioners of Kunlun Station, under the organization of the administration, we carried out medical screening in Tibet before departure to exclude the hypoxia-susceptible people. When expeditioners took plane from Shanghai (4 m) to Lhasa (3650 m), and then to Yambajan (4300 m) by bus, their physiopsychological changes were dynamically monitored, and AMS incidence was assessed daily. We divided the expeditioners into AMS-susceptible (AMS-S) and AMS-resistant (AMS-R) groups according to AMS occurrences in Yambajan. Through comparing physiopsychological data between AMS-S and AMS-R groups, we tried to find out some physiopsychological indicators which could be used as clues for screening hypoxia-susceptible individuals.

2 Materials and methods

2.1 Participants and procedure

After the clinical physical examination, 27 qualified healthy males from the 37th Chinese Antarctic pre-selected expedition of Kunlun Station participated in this study. Their ages were between 21 and 45 a (31.9±6.1 a). The itinerary and schedule of physiopsychological tests of the pre-selected expeditioners are shown in Figure 1. The pre-selected expedition team flew into Lhasa from Shanghai, took the bus to Yambajan after 3 d of training in Lhasa, and returned to Lhasa by bus after 3 d of training in Yambajan. On the next day, they returned to their living places by

plane. Oxygen saturation, pulse rate, blood pressure, heart rate and AMS occurrences were assessed daily. Other data, including electrocardiogram (ECG), cardiovascular function, pulmonary function, and mood states, were collected before departure from Shanghai, on the 2nd day in Lhasa and on the 2nd day in Yambajan.

According to the criteria of AMS evaluation, we eliminated 2 expeditioners with headache in Shanghai and 1 expeditioner who left during the training. The data from 24 participants were analyzed. When expeditioners took physiopsychological examinations on the 2nd day in Yambajan, 7 of them were AMS-S, while 17 of them were AMS-R. Based on the occurrence of AMS in Yambajan where hypoxic conditions were even worse, the team was divided into AMS-S and AMS-R groups.

2.2 Instrumental examinations

The instrumental examinations were carried out during resting state of expeditioners at room temperature (22–25°C), and the results were evaluated by clinical experts.

Blood pressure and heart rate (HR) were measured by an electronic sphygmomanometer (HEM7211, OMRON, Japan). Parameters of blood pressure include diastolic blood pressure (DBP) and systolic blood pressure (SBP). Oxygen saturation (SpO₂) and pulse rate were measured by a pulse oximeter (DB18, Philips, USA).

ECG was recorded by a 12-lead electrocardiograph (MAC800, GE, USA), and 10 parameters were obtained, including HR, interval from the beginning to the end of QRS complex wave (QRS), interval from the beginning of QRS complex wave to the end of T wave (QT), HR-corrected QT interval (QTc), interval from the beginning of P wave to the beginning of QRS complex wave (PR), interval between 2 adjacent R waves (RR), interval between 2 adjacent P waves (PP), axis of QRS complex wave (QRS axis), axis of T wave (T axis) and axis of P wave (P axis). The P wave represents atrial depolarization, the QRS complex wave represents ventricular depolarization, and the T wave represents ventricular repolarization.

Cardiovascular function was examined by a noninvasive hemodynamic monitor (NiccomoTM Cardioscreen® 2000, Medis, German), and it accessed 36 parameters. Vital signs included SpO₂, oxygen delivery index (DO₂I), HR, heart period (HPD), SBP, DBP, mean arterial pressure (MAP) and pulse pressure (PP). Parameters of thoracic fluid content included base impedance (Z₀), thoracic fluid content (TFC) and thoracic fluid content index (TFCI). Parameters of cardiac pumping included stroke volume (SV), stroke volume variation (SVV), stroke index (SI), cardiac output (CO) and cardiac index (CI). Parameters of cardiac contractility included velocity index (VI), acceleration index (ACI), Heather index (HI), pre-ejection period (PEP), left ventricular ejection time (LVET), systolic time ratio (STR), systolic time ratio index

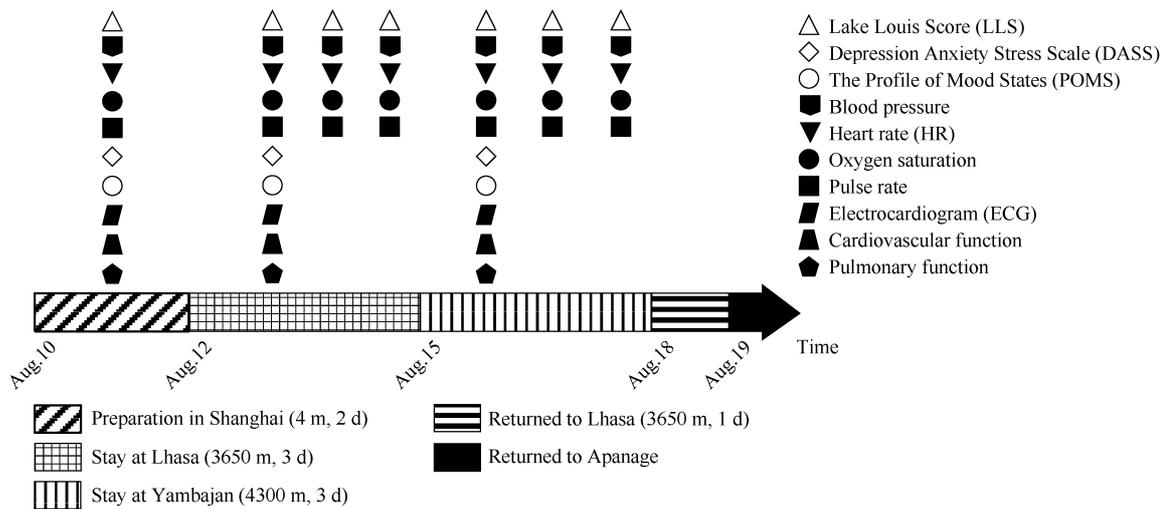


Figure 1 The itinerary and schedule of physiopsychological tests of the pre-selected expeditioners of Kunlun Station ($n=27$).

(STRI), ejection time index (ETI), ejection time ratio (ETR) and flow time corrected (FTc). Parameters of cardiac work included cardiac power (CPO), cardiac power index (CPI), left cardiac work (LCW), left cardiac work index (LCWI) and left stroke work index (LSWI). Parameters of systemic vascular resistance included total arterial compliance (TAC), total arterial compliance index (TACI), systemic vascular resistance (SVR), systemic vascular resistance index (SVRI) and stroke systemic vascular resistance index (SSVRI).

Pulmonary function was examined by a digital spirometer (MasterScope®, Jaeger, German), 12 parameters were recorded. Vital capacity maximum (VC_{max}) and forced vital capacity (FVC) reflected vital capacity. Forced expiratory volume in 1s (FEV_1) and FEV_1/FVC reflected pulmonary ventilatory function. Peak inspiratory flow (PIF), peak expiratory flow (PEF) and maximal expiratory flow at 75% of FVC (MEF_{75}) reflected large airways ventilatory function. Maximal inspiratory flow at 50% of FVC (MIF_{50}), maximal expiratory flow at 25% of FVC (MEF_{25}), maximal expiratory flow at 50% of FVC (MEF_{50}), and maximal mid-expiratory flow (MMEF) reflected small airways ventilatory function. MEF_{50}/MIF_{50} reflected the site of airway obstruction.

2.3 Questionnaires

Lake Louise Score (LLS) was adopted to evaluate the incidence of AMS (Roach et al., 2018). The 5 main symptoms were evaluated, including headache, gastrointestinal symptoms, fatigue and/or weakness, dizziness/light-headedness, and sleep difficulty (Hackett and Oelz, 1992). Expeditioners whose total scores of $LLS \leq 2$ were determined as AMS-R, while those whose total scores ≥ 3 along with headache were determined as AMS-S (Julian et al., 2011). 3–5 points are mild AMS, 6–9 points are moderate AMS, and 10–12 points are severe AMS (Roach et al., 2018).

Depression Anxiety Stress Scale (DASS) was used to assess some core symptoms of depression, anxiety and

stress (Norton, 2007). The Profile of Mood States (POMS) was used to assess 6 dimensions of mood, i.e. vigor-activity, tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia and confusion-bewilderment (McNair et al., 1971).

2.4 Statistical analysis

Continuous data were expressed as mean \pm SD, discontinuous data were expressed as median (interquartile range). All data were analyzed using IBM SPSS Statistics 25 software (SPSS Inc, Chicago, IL). Normal distribution was tested by the Shapiro-Wilks test. Data with normal distribution were analyzed by T test. Abnormally distributed data were analyzed by the Friedman test. When $P < 0.05$, data were considered to be significantly different.

3 Results

3.1 Demographic and physiological characteristics

When expeditioners took physiopsychological examinations on the 2nd day in Yambajan, 7 of them were AMS-S, while 17 of them were AMS-R. Based on the occurrence of AMS in Yambajan where hypoxic conditions were even worse, the team was divided into AMS-S and AMS-R groups. In the AMS-S group, all were mildly AMS.

There were no significant differences in demographic and physiological characteristics between the AMS-S and AMS-R groups before departure from Shanghai (Table 1).

3.2 Changes of SpO_2 , HR, blood pressure and pulse rate

Compared with before departure from Shanghai, in Lhasa and Yambajan, DBP, HR and pulse rate of expeditioners significantly increased, SpO_2 significantly decreased, and SBP significantly increased only in Lhasa ($P < 0.05$)

Table 1 Demographic and physiological characteristics

Parameters	Shanghai (4 m)		Yambajan (4300 m)	
	AMS-R (n=17)	AMS-S (n=7)	AMS-R (n=17)	AMS-S (n=7)
Age/a	32.12±4.81	31.43±8.06		
Height/cm	171.71±5.41	172.93±3.40		
Weight/kg	70.38±8.54	73.36±15.24	70.65±8.20	73.49±14.66
Body mass index (BMI)/(kg·m ⁻²)	23.92±2.99	24.46±4.53	24.21±3.06	24.53±4.41
Systolic blood pressure (SBP)/mmHg	127.71±9.97	134.00±13.80	129.59±11.85	130.83±13.38
Diastolic blood pressure (DBP)/mmHg	77.94±9.86	81.57±12.53	86.18±10.25***	88.33±8.76*
Heart rate (HR)/bpm	71.29±9.82	69.71±10.90	105.53±16.05***	103.67±14.96**
Oxygen saturation (SpO ₂)/%	97.24±0.75	96.86±0.38	82.59±6.04***	81.00±5.89*
Pulse rate/bpm	73.29±9.48	69.71±8.11	103.94±16.54***	103.28±14.06**

Notes: (1) Data were expressed as mean ± SD. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$ vs control group in Shanghai.

(2) AMS-R, AMS-resistant group; AMS-S, AMS-susceptible group; bpm, beat per minute.

(3) Blood pressure, HR, SpO₂ and pulse rate were measured in the sitting position.

(Figure 2). There were no significant differences in SpO₂, HR, blood pressure and pulse rate between AMS-S and AMS-R groups.

3.3 Changes of ECG

Compared with before departure from Shanghai, ECG conduction of expeditioners changed in Yambajan (Table 2). HR and QTc of both AMS-S and AMS-R groups significantly increased ($P < 0.01$). However, QT, QRS, PP and RR significantly shortened ($P < 0.05$). There were no significant differences of ECG conduction between AMS-S and AMS-R groups.

3.4 Changes of cardiovascular function

When expeditioners arrived in Yambajan, compared with before departure from Shanghai, in both AMS-S and AMS-R groups, SpO₂, DO₂I and HPD significantly

decreased, HR, SBP, DBP and MAP significantly increased ($P < 0.01$). For cardiac pumping function, SV, SI, CO and CI significantly decreased ($P < 0.01$). For cardiac contractility, VI, ACI, HI and LVET significantly decreased, STR, STRI and ETR significantly increased ($P < 0.01$). For systemic vascular resistance, TAC and TACI significantly decreased, but SVR, SVRI and SSVRI significantly increased ($P < 0.01$, Table 3).

Compared with AMS-R group, AMS-S group showed significantly lower SpO₂ and higher SVV before departure from Shanghai ($P < 0.05$).

3.5 Changes of pulmonary function

Compared with before departure from Shanghai, only FEV₁/FVC significantly increased in both AMS-S and AMS-R groups in Yambajan ($P < 0.01$). VC_{max}, FEV₁, PIF, PEF, MEF₅₀, MEF₇₅, and MMEF only significantly increased in AMS-R group in Yambajan ($P < 0.05$, Table 4).

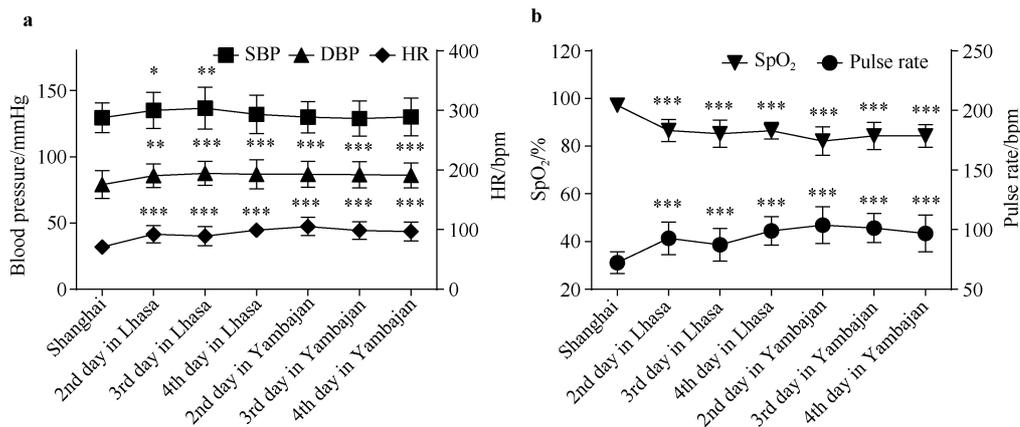


Figure 2 Changes of blood pressure and SpO₂ of the pre-selected expeditioners at different altitudes (n=24). Notes: (1) Data were expressed as mean ± SD. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, vs control group in Shanghai. (2) SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; SpO₂, oxygen saturation. (3) All parameters were measured in the sitting position.

Table 2 Differences in ECG between AMS-R group and AMS-S group

Parameters	Shanghai (4 m)		Yambajan (4300 m)	
	AMS-R (n=17)	AMS-S (n=7)	AMS-R (n=17)	AMS-S (n=7)
HR/bpm	71.65±11.18	70.57±7.93	89.94±12.97***	91.57±12.26**
QT/ms	385.88±25.07	384.00±19.53	362.00±24.28***	361.71±26.52*
QTc/ms	417.88±18.33	414.14±18.12	439.53±18.20***	443.86±21.54***
QRS/ms	93.06±14.00	91.71±7.06	88.24±13.30**	87.43±6.70*
PR/ms	144.59±18.40	156.00±21.79	147.29±32.46	150.86±15.91
PP/ms	856.06±132.67	859.00±95.96	679.82±98.42***	664.14±83.19***
RR/ms	854.59±130.28	856.86±96.19	679.29±98.35***	664.29±83.20***
P axis(°)	58.76±19.36	56.43±19.11	62.59±24.33	61.29±13.11
QRS axis(°)	69.47±24.70	59.71±21.42	65.71±35.48	61.71±26.22
T axis(°)	43.75±18.02	41.57±16.05	45.88±15.68	44.43±13.70

Notes: (1) Data were expressed as mean ± SD. **P* < 0.05, ***P* < 0.01, ****P* < 0.001 vs control group in Shanghai.

(2) AMS-R, AMS-resistant group; AMS-S, AMS-susceptible group; °, degree.

(3) QRS, interval from the beginning to the end of QRS complex wave; QT, interval from the beginning of QRS complex wave to the end of T wave; QTc, HR-corrected QT interval; PR, interval from the beginning of P wave to the beginning of QRS complex wave; PP, interval between 2 adjacent P waves; RR, interval between 2 adjacent R waves; P axis, axis of P wave; QRS axis, axis of QRS complex wave; T axis, axis of T wave.

(4) All parameters were measured in the lying position.

Table 3 Differences in cardiovascular function between AMS-R and AMS-S expeditioners

Parameters	Shanghai (4 m)		Yambajan (4300 m)	
	AMS-R (n=17)	AMS-S (n=7)	AMS-R (n=17)	AMS-S (n=7)
Oxygen saturation (SpO ₂)/%	97.12±1.32	95.86±0.90 [#]	84.18±5.78***	81.00±3.27*
Oxygen delivery index (DO ₂ I)/(mL·min ⁻¹ ·m ⁻²)	695.41±110.42	706.00±69.34	520.18±108.16***	508.29±47.72***
Heart rate (HR)/bpm	72.76±12.29	68.86±8.99	93.12±15.59***	94.86±12.13**
Heart period (HPD)/ms	846.18±130.15	883.57±112.38	663.41±120.00***	640.14±80.49**
Systolic blood pressure (SBP)/mmHg	127.35±12.76	122.29±8.71	139.65±15.85**	144.71±19.72*
Diastolic blood pressure (DBP)/mmHg	74.65±8.93	73.14±3.53	87.18±12.22***	91.29±11.10**
Mean arterial pressure (MAP)/mmHg	84.88±10.43	82.57±3.60	98.47±13.73**	102.57±13.10**
Pulse pressure (PP)/mmHg	52.76±7.05	47.57±7.32	52.47±7.53	53.43±12.62
Base impedance (Z ₀)/Ω	40.36±5.09	39.83±2.34	44.01±3.61**	43.76±3.86*
Thoracic fluid content (TFC)/kΩ ⁻¹	25.18±3.43	25.17±1.46	22.88±1.82**	23.00±2.20*
Thoracic fluid content index (TFCI)/(kΩ ⁻¹ ·m ⁻²)	13.84±2.06	13.64±1.59	12.56±1.09**	12.54±2.18
Stroke volume (SV)/mL	82.88±17.03	90.43±7.41	56.35±15.29***	56.57±10.08***
Stroke index (SI)/(mL·m ⁻²)	45.47±8.50	48.57±3.82	30.94±8.15***	30.43±5.00***
Stroke volume variation (SVV)/%	15.94±5.75	12.57±1.62 [#]	18.76±6.17	17.57±4.86*
Cardiac output (CO)/(L·min ⁻¹)	5.94±1.08	6.19±0.71	5.08±0.98**	5.29±0.76**
Cardiac index (CI)/(L·min ⁻¹ ·m ⁻²)	3.25±0.51	3.34±0.34	2.79±0.49**	2.84±0.32**
Velocity index (VI)/(10 ⁻³ ·s ⁻¹)	54.18±13.32	58.86±13.75	35.53±13.00***	33.86±8.34**
Acceleration index (ACI)/(10 ⁻² ·s ⁻²)	90.24±26.53	100.71±25.51	76.88±20.48***	66.00±13.92**
Heather index (HI)/(Ω·s ⁻²)	19.29±5.44	20.96±4.92	14.84±5.68**	13.24±2.49**
Pre-ejection period (PEP)/ms	99.59±10.18	100.57±8.90	100.18±11.54	100.43±9.40
Left ventricular ejection time (LVET)/ms	285.76±18.24	293.29±16.90	247.12±25.26***	245.71±23.26**
Systolic time ratio (STR)	0.35±0.04	0.34±0.04	0.41±0.07**	0.41±0.04**
Systolic time ratio index (STRI)/s ⁻¹	0.43±0.10	0.39±0.07	0.64±0.19***	0.65±0.13**

Continued

Parameters	Shanghai (4 m)		Yambajan (4300 m)	
	AMS-R (n=17)	AMS-S (n=7)	AMS-R (n=17)	AMS-S (n=7)
Ejection time ratio (ETR)/(%)	34.29±3.69	33.29±3.35	37.65±2.98**	38.57±2.76**
Ejection time index (ETI)/ms	402.47±10.41	403.71±12.05	396.00±7.22	398.14±11.99
Flow time corrected (FTc)/ms	312.12±12.30	313.00±13.89	304.47±10.90	307.57±16.74
Cardiac power (CPO)/w	1.10±0.23	1.10±0.15	1.09±0.21	1.18±0.16
Cardiac power index (CPI)/(w·m ⁻²)	0.60±0.11	0.60±0.04	0.60±0.10	0.63±0.04
Left cardiac work (LCW)/(kg·m)	6.40±1.44	6.49±0.77	6.42±1.27	7.01±0.98
Left cardiac work index (LCWI)/(kg·m ⁻²)	3.49±0.72	3.47±0.24	3.51±0.64	3.76±0.27
Left stroke work index (LSWI)/(g·m·m ⁻²)	48.41±8.43	50.71±3.86	38.35±6.92***	39.71±3.09***
Total arterial compliance (TAC)/(mL·mmHg ⁻¹)	1.60±0.43	1.90±0.25	1.08±0.29***	1.14±0.44**
Total arterial compliance index (TACI)/(mL·m ⁻² ·mmHg ⁻¹)	0.88±0.23	1.03±0.17	0.60±0.16***	0.62±0.25**
Systemic vascular resistance (SVR)/(dyn·s·cm ⁻⁵)	1107.24±237.74	1014.29±116.63	1521.53±450.84**	1497.00±376.38*
Systemic vascular resistance index (SVRI)/(dyn·s·cm ⁻⁵ ·m ²)	2009.82±395.20	1885.00±244.90	2770.94±856.14**	2772.29±690.00*
Stroke systemic vascular resistance index (SSVRI)/(dyn·s·cm ⁻⁵ ·m ²)	145.94±44.23	129.14±16.05	263.71±115.83***	264.71±75.74*

Notes: (1) Data were expressed as mean ± SD. **P* < 0.05, ***P* < 0.01, ****P* < 0.001 vs control group in Shanghai. #*P* < 0.05, vs AMS-R group.
 (2) AMS-R, AMS-resistant group; AMS-S, AMS-susceptible group; w, watt; dyn, dyne; Ω, ohm.
 (3) All parameters were measured in the lying position.
 (4) 1 mmHg = 133.322 Pa.

Table 4 Differences in pulmonary function between AMS-R and AMS-S expeditioners

Parameters	Shanghai (4 m)		Yambajan (4300 m)	
	AMS-R (n=17)	AMS-S (n=7)	AMS-R (n=17)	AMS-S (n=7)
Vital capacity maximum (VC _{max})/L	4.36±0.51	4.35±0.55	4.69±0.71*	4.47±0.61
Forced vital capacity (FVC)/L	4.27±0.51	4.30±0.55	4.31±0.50	4.03±0.64
Forced expiratory volume in 1 s (FEV ₁)/L	3.75±0.42	3.62±0.41	3.90±0.53*	3.55±0.63
FEV ₁ /FVC/%	87.96±5.43	84.72±8.58	90.67±7.72*	88.29±9.98*
Peak inspiratory flow (PIF)/(L·s ⁻¹)	4.63±2.03	4.90±1.80	7.06±2.95**	6.05±1.60
Peak expiratory flow (PEF)/(L·s ⁻¹)	8.00±1.13	7.82±1.31	9.3±1.61***	8.77±1.70
Maximal expiratory flow at 25% of FVC (MEF ₂₅)/(L·s ⁻¹)	2.17±0.78	1.92±0.92	2.24±0.91	1.92±1.18
Maximal expiratory flow at 50% of FVC (MEF ₅₀)/(L·s ⁻¹)	5.09±0.92	4.30±1.19	5.64±1.34*	4.52±2.21
Maximal expiratory flow at 75% of FVC (MEF ₇₅)/(L·s ⁻¹)	7.45±1.10	6.59±1.21	8.86±1.59***	7.17±1.93#
Maximal mid-expiratory flow (MMEF)/(L·s ⁻¹)	4.27±0.96	3.74±1.20	4.74±1.26*	3.95±1.95
MEF ₅₀ /MIF ₅₀ %	156.88±114.23	117.43±67.57	112.46±72.07	93.01±74.73

Notes: (1) Data were expressed as mean ± SD. **P* < 0.05, ***P* < 0.01, ****P* < 0.001 vs control group in Shanghai. #*P* < 0.05, vs AMS-R group.
 (2) AMS-R, AMS-resistant group; AMS-S, AMS-susceptible group.
 (3) All parameters were measured in the sitting position.

Compared with AMS-R group, AMS-S group in Yambajan showed significantly lower MEF₇₅ (*P*<0.05).

3.6 Changes of mood states

Compared with before departure from Shanghai, after arriving in Yambajan, the level of anxiety significantly increased only in AMS-S group, the levels of depression

and anger significantly decreased only in AMS-R group (*P*<0.05, Table 5). According to the diagnostic criteria of DASS, the anxiety level of AMS-S group was normal in Yambajan.

Compared with AMS-R group, the levels of anxiety, confusion and fatigue significantly increased in AMS-S group in Yambajan (*P*<0.05).

Table 5 Differences in mood state between AMS-R and AMS-S expeditioners in Tibet

Questionnaires	Parameters	Shanghai (4 m)		Yambajan (4300 m)	
		AMS-R (n=17)	AMS-S (n=7)	AMS-R (n=17)	AMS-S (n=7)
Depression Anxiety Stress Scale (DASS)	Depression	0.0 (0.0, 1.0)	0.0 (0.0, 2.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)
	Anxiety	2.0 (0.0, 4.0)	0.0 (0, 6.0)	2.0 (1.0, 5.0)	8.0 (6.0, 8.0)*#
	Stress	2.0 (0.0, 9.0)	4.0 (0, 6.0)	2.0 (0.0, 5.0)	4.0 (2.0, 6.0)
The Profile of Mood States (POMS)	Tension	-1.0 (-3.0, 3.5)	0.0 (0.0, 4.0)	-2.0 (-3.5, 1.0)	2.0 (-1.0, 4.0)
	Depression	1.0 (0.0, 9.0)	2.0 (0.0, 7.0)	0.0 (0.0, 1.5)*	1.0 (0.0, 3.0)
	Anger	0.0 (0.0, 4.0)	2.0 (0.0, 5.0)	0.0 (0.0, 0.5)*	0.0 (0.0, 1.0)
	Vigor	20.0 (19.0, 23.0)	22.0 (16.0, 24.0)	16.0 (14.0, 23.5)	16.0 (15.0, 22.0)
	Fatigue	1.0 (0.0, 6.5)	2.0 (1.0, 4.0)	2.0 (0, 5.0)	5.0 (4.0, 7.0)#
	Confusion	-2.0 (-3.0, 2.0)	0.0 (-2.0, 1.0)	-2.0 (-3.0, -0.5)	1.0 (-1.0, 2.0)#
	Total mood disturbance (TMD)	-19.0 (-26.5, 8.0)	-7 (-20.0, 4.0)	-15.0 (-26.0, -10.0)	-9.0 (-16.0, 3.0)

Notes: (1) Data were expressed as median (interquartile range). * $P < 0.05$, vs control group in Shanghai. # $P < 0.05$, vs AMS-R group.

(2) AMS-R, AMS-resistant group; AMS-S, AMS-susceptible group.

4 Discussion

Hypoxia is the greatest challenge for expeditioners at Kunlun Station (4087 m). Therefore, through dynamically monitoring changes of AMS incidence, cardiopulmonary function and mood states of the 37th Chinese Antarctic pre-selected expeditioners of Kunlun Station from Shanghai (4 m) to Lhasa (3650 m) and Yambajan (4300 m), we obtained physiopsychological data of AMS-S and AMS-R groups. By comparing different changes of AMS-S and AMS-R groups, our study found that compared with AMS-R group, AMS-S group had lower SpO₂ and higher SVV before departure from Shanghai, lower MEF₇₅ and higher levels of negative moods, including anxiety, confusion, fatigue, in Yambajan.

Our study found SpO₂ decreased, while blood pressure and HR increased when expeditioners arrived in Tibet. In hypoxic environments, the oxygen content of the breath decreased, SpO₂ decreased, and would stimulate the peripheral chemoreceptors, leading to increase of sympathetic activity (Bartsch and Gibbs, 2007). As a result, HR, SBP, DBP and pulse rate increased. Previous studies reported that SpO₂ can be used to predict the development of AMS (Liu et al., 2014; Burtscher et al., 2019). Our results also showed that expeditioners with lower SpO₂ before departure were at increased risk for AMS when arrived in Yambajan.

We didn't find differences in ECG between AMS-R and AMS-S groups. But after reaching 4300 m, our results showed that QTc lengthened, while QT, QRS, RR and PP shortened in both AMS-S and AMS-R groups. ECG changes under hypoxia condition are related to energy metabolism. Our previous research (Guo et al., 2012) conducted in the 25th and 26th Chinese Antarctic pre-selected expeditioners of Kunlun Station found that

after entering the plateau by train, at 4300 m, their QTc lengthened, but QRS shortened. This was consistent with our result.

Hypoxia at high altitude could reduce cardiovascular function. Stembridge et al. (2019) found that 12 healthy adult men showed reduced stroke volume (SV) and left ventricular diastolic volume at 3800 m. Sareban et al. (2019) found that after rapid ascent to 4559 m, left ventricular passive filling volume and SV of 50 healthy subjects decreased. Our group (Guo et al., 2012) found that at 3650 m and 4300 m, systemic vascular resistance (SVR) of the 25th and 26th Chinese Antarctic pre-selected expeditioners of Kunlun Station increased, while left ventricular pumping and contractile function weakened. This study is consistent with previous reports. Under hypoxic environments at 4300 m, left ventricular systolic and pumping function of both AMS-S and AMS-R groups decreased. Meanwhile, systemic vascular resistance increased. Acute hypoxia can cause transient pulmonary hypertension, and then increase pulmonary vascular resistance, leading to right ventricular dilatation. As a result, left ventricular diastolic volume decreased correspondingly (Mahmud et al., 2002). Therefore, SV and SI reduced, while SVR increased. Due to reduced oxygen supply, energy metabolism is impaired and myocardial energy supply is inadequate, resulting in decreased myocardial contractility (Chacaroun et al., 2016). Our study also found decreases in velocity index (VI), acceleration index (ACI) and left ventricular ejection time (LVET), increases in systolic time ratio (STR) and ejection time ratio (ETR). Under hypoxia conditions, increased sympathetic activity could lead to persistent vascular tension (Duplain et al., 1999), coupled with reduced reflex sensitivity of vascular baroreflex (Cooper et al., 2005). These changes lead to reduced vasodilation response, thus, resulting in increased SVR. Our results also showed expeditioners with higher SVV were

susceptible to AMS when arrived in Yambajan. The relationship between SVV and AMS hadn't been reported, which needs further research in the following pre-selected expeditions.

Previous studies have reported pulmonary ventilation function changed in hypoxia environments. Cremona et al. (2002) found FEV₁/FVC increased when 262 climbers arrived at 4559 m. Dehnert et al. (2010) found FEV₁/FVC and MMEF of 34 subjects significantly increased at 4559 m. Our study found VC_{max}, FEV₁/FVC, PEF, PIF, MEF₅₀, MEF₇₅ increased after reaching 4300 m. Under hypoxic conditions, decreased PO₂ in blood caused hyperventilation (Burgess and Ainslie, 2016). Pulmonary function can be used to monitor the occurrence of AMS (Roach et al., 2000; Beidleman et al., 2004). Yang et al. (2020) took pulmonary function tests on 121 healthy men at 4100 m, they suggested that subjects with low MEF₇₅ (FEF₂₅) values at low altitude are susceptible to high levels of pulmonary artery pressure at high altitude but not the incidence of AMS following short-term high-altitude exposure. But our results also found expeditioners who were susceptible to AMS had lower MEF₇₅ in Yambajan, indicating that expeditioners with good big airway ventilation at high altitude may be tolerant to hypoxia.

Hypoxia at high altitude can cause mood disorders. In hypoxic environments, low oxygen led to increase of sympathetic activity (Bärtsch and Gibbs, 2007), which may impair mood states. Our study found anxiety, fatigue, and confusion of AMS-S group increased in Yambajan compared to AMS-R group. These were coincidence with several studies. Boos et al. (2018) found anxiety at high altitude was independently associated with AMS and its severity. Fatigue was one of the main symptoms of AMS. de Aquino Lemos et al. (2012) also found fatigue increased and vigor reduced in 10 healthy men after arriving at 4500 m. Bian et al. (2015) analyzed risk factors of AMS in 163 participants who were acute exposure 3700 m, they found the AMS population exhibited more negative mood states, including anxiety, depression, hostility, fatigue and confusion.

Limited by one-week adaptive training in Tibet, our study only monitored physiopsychological changes of pre-selected expeditioners of Kunlun Station during the acute period of hypoxia. Although we have suggested some physiopsychological indicators which may be used as clues for screening hypoxia-susceptible individuals, however, because of the small sample size in this study, we still need to accumulate more data from multiple teams to verify our findings.

5 Conclusion

Our study found that cardiopulmonary function and mood states could be affected when expeditioners were acutely exposed to 4300 m. After comparing the differences of physiopsychological parameters between AMS-S and

AMS-R groups at Shanghai and Yambajan, we found that compared with AMS-R group, AMS-S group showed significantly lower SpO₂ and higher SVV before departure in Shanghai, however, significantly lower MEF₇₅, higher levels of anxiety, fatigue and confusion in Yambajan. Maybe these changed physiopsychological parameters could be used as clues for screening hypoxia-susceptible individuals.

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