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516 例参训官兵高原反应测试分析 *

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摘要 目的:探讨在模拟不同海拔高度时,拟赴高原的参训官兵在急进高原时高原反应发生的特点,为高原参训官兵高原病的预防提供理论依据。**方法:**应用西北特殊环境人工实验舱模拟不同海拔高度,随机对 516 名平原部队参训官兵进行急进不同海拔高原反应进行测试,动态观察平原环境、急进高原 2000 m、3000 m、4500 m 海拔高度的自觉症状及部分生理指标(心率、血氧饱和度)的动态变化以及进舱前和出舱后血压值变化情况。**结果:**(1)516 名官兵均完成测试,在海拔 2000 m 时,53 例出现耳闷、耳涨症状,94 例出现耳鸣症状,作吞咽动作后在以后的"上升"和"下降"过程中均未出现症状;在海拔 4500 m 时,39 例出现高原反应,其中 19 例出现头晕症状,20 例出现手足麻木,高原反应发生率 7.56%。(2)随着海拔高度逐渐升高,受试者心率逐渐加快,从 2000 m 开始加快明显($p<0.05$),血氧饱和度逐渐降低,到 3000 m 开始血氧饱和度下降明显($p<0.05$)。(3)进舱前和出舱后血压值相比没有统计学差异($p>0.05$)。**结论:**参训官兵急进高原后,高原反应主要出现在 4500 m 海拔高度,高原反应发生率 7.56%;高原环境对机体的心率、血氧饱和度的影响随着海拔高度增加而明显,2000 m 开始心率明显加快,3000 m 开始出现血氧饱和度明显下降,耳部不适症状主要出现在 2000 m,但在做吞咽动作后消失。

关键词:高原;模拟环境;参训官兵;高原反应测试
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Analysis of 516 Cases of Altitude Stress Testing of Training Officers and Soldiers under Simulated High Altitude Environment *

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ABSTRACT Objective: To invesigate the characteristics of altitude stress of training officers and soldiers rapid entering high altitude in simulated environment, and provide a theoretical basis for the prevention of plateau disease. **Methods:** A total of 516 training officers and soldiers were tested in our "Simulated Climate Cabin for Special Environment of Northwest of China". Their discomfort symptoms and physiological indexes (heart rate, blood oxygen saturation) were recorded when simulated altitude in the hypobaric chamber was elevated to 2000 m, 3000 m, 4500 m and descended to the plain at each time. The changes of their blood pressure were observed after they came out of the chamber and compared with those they went into the chamber before. **Results:** (1) Of the 516 subjects who subjected to hypobaric chamber examination, there were aural fullness in 53 cases and tinnitus symptoms in 94 cases at the altitude of 2000 m, however, after swallowing, none of the discomfort appeared again in the process of "rising" and "falling", 39 cases had altitude sickness, of which dizziness occurred in 19 cases, and hand foot numbness occurred in the 20 cases at the altitude of 4500m, the incidence of altitude sickness was about 7.56%. (2) With the altitude increasing, the heart rate of the subjects was accelerated significantly at 2000 m($p<0.05$), and the blood oxygen saturation decreased significantly at 3000 m($p<0.05$). (3) Before and after entering the chamber, there was no significant difference in blood pressure($p>0.05$). **Conclusions:** Altitude sickness mainly occurred at 4500m and the incidence was 7.56%; Effects of the heart rate and blood oxygen saturation for the subjects were increased obviously with the increasing altitude, the heart rate of the subjects was accelerated significantly at 2000 m, and the blood oxygen saturation of the subjects was decreased significantly at 3000 m. The ear discomfort symptoms of the subjects mainly occurred at 2000 m, but it was disappeared after swallowing.

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前言

海拔高于 3000 m 以上地区的高原环境因大气压较正常海平面减低，具有低压、缺氧、高寒等显著特征。低压、缺氧是影响人体最严重和最明显的不利因素。平原人急进高原后，其低压缺氧等因素刺激对人体的生理状况影响很大[1-3]。随着我军 " 提高作战能力 " 战略的全面推进，研究高原边远艰苦地区恶劣自然环境条件对官兵生理指标及自觉症状的变化，对于了解此条件下官兵习服适应的规律，在保障高原官兵健康、提高作战能力方面均具有重要的经济和军事意义。

低压舱是通过对舱内可控式定量抽气模拟高海拔地区稀薄的大气环境，可以相对真实地模拟高原主要气候条件的大型专用研究设备，主要用于多个环境因素实验基础研究、飞行员医学选拔、航空生理训练、医学鉴定及心理测试、运动员高空高海拔环境训练、官兵进入高原前耐低氧测试以及习服锻炼等研究工作[4-6]。有关低压缺氧特殊环境相关研究报道较多[7-10]，但对于平原健康官兵在急进不同海拔高度高原适应性的测试研究资料尚缺乏。新疆军区总医院研制的 " 西北特殊环境人工实验舱 "[9,11]，可模拟不同海拔高原环境变化，对拟赴高原旅游、训练人员进行高原缺氧环境时的适应性测试，为高原军事医学研究的重要平台。国内有低压复合舱的单位不多，对拟赴高原参训人员提前进行高原适应性测试的工作目前在国内外少有报道。本研究对拟赴高原训练的新疆某部健康官兵进行高原反应测试，观察其急进入不同海拔高度(2000 m、3000 m、4500 m)时的部分生理指标变化(心率(Heart Rate，HR)、血压、血氧饱和度(the blood oxygen saturation，SaO_2)以及自觉症状改变(头痛、头晕、气短、胸闷、恶心、耳涨、耳鸣、手足麻木)等适应性测试状况，并分别与地面正常海拔上述指标进行比较，现报道如下。

1 对象与方法

1.1 对象

选择新疆某综合训练基地官兵 516 例，健康男性，汉族，年龄 19～40 岁，平均年龄 22.86± 3.95 岁，体重 58.23± 4.06 Kg，身高 170.00± 2.40 cm，均为初次进入高原环境，获知情同意并签署知情同意书。进低压舱前均询问既往病史、详查查体，进行心电图、电耳镜及鼻内镜检测，确定无低压舱检查禁忌症。

1.2 方法

测试前首先告知检查目的、方法和注意事项：1)所有受检者进舱之前仔细聆听低压舱进舱宣教内容、签订测试知情同意书并能密切配合；2)受试者坐于低压舱内，以 1 m/s 的速度 " 上升 " 和 " 下降 " 至每一个检测海拔高度时停留 5 min，按照人手一张低压舱不同海拔高度自觉症状记录表内容(头痛、头晕、气短、胸闷、恶心、耳涨、耳鸣、手足麻木)如实填写，同时随舱医务人员会及时提醒并提供帮助；3)经校准后的指夹式脉搏血氧仪(深圳和心重典医疗设备有限公司、ZONDRN)夹在受试者左手食指处，按压测量键屏幕即可显示测量值(血氧饱和度测量范围：35-99%，心率测量范围：30-240BPM)并将测量值填入表格相应海拔处；4) 电子血压仪 (欧姆龙有限公司、OMRON、HEM-7200)测定进舱前和出舱后即刻血压值；5)对受试者分别依次检测 2000 m，3000 m，4500 m 海拔高度的自觉症状、心率、血氧饱和度的变化，并分别与地面正常海拔进行比较。所有进行的研究分析均为自身对照研究。

1.3 观测生理指标判定标准

心率：HR＞100 min^{-1} 和 / 或＜60 min^{-1} 为异常；血氧饱和度：SaO_2≤ 85%为异常；

血压：收缩压(SBP)≥ 140 mmHg 和 / 或＜90 mmHg，舒张压(DBP)≥ 90mmHg 和 / 或＜60 mmHg 均为异常。

1.4 统计学分析

采用 SPSS21.0 软件进行统计学分析，数据均以均数± 标准差($\bar{x}\pm s$)表示，多组间计量资料采用单因素方差分析，两组间比较采用 SNK-q 检验，计数资料用 x^2 检验，以 $p<0.05$ 为差异有统计学意义。

2 结果

516 例受试者均能了解此项测试的全过程，能密切配合并完成该测试。

2.1 不同海拔高度自觉症状情况

所有受试者在不同海拔高度均未出现头痛、气短、胸闷、恶心症状；在海拔 4500 m 时，19 例出现头晕症状，20 例出现手足麻木，" 下降 " 后均有好转，高原反应发生率 7.56%；在海拔 2000 m 时，53 例出现耳闷、耳涨症状，94 例出现耳鸣症状，作了吞咽动作后在以后的 " 上升 " 和 " 下降 " 过程中均未再次出现，见表 1。

表 1 不同海拔高度自觉症状分布(例数)

Table 1 Distribution of subjective symptoms at different altitudes(cases)

Altitued(m)	Headache	shorteness of breath	Nausea	Dizziness	Deadlimb	Aural fullness	Tinnitus
0	0	0	0	0	0	0	0
2000	0	0	0	0	0	53	94
3000	0	0	0	0	0	0	0
4500	0	0	0	19	20	0	0

2.2 不同海拔高度 HR、SaO_2 的变化

受试者心率随着低压舱内不同海拔高度的 " 上升 " 或 " 下降 " 而加快或减慢，二者呈正相关；血氧饱和度的变化则是随着低压舱内不同海拔高度 " 上升 " 或 " 下降 " 而降低或升高，两者呈反相关；至模拟海拔 4500m 时，受试者心率、血氧饱和度与进舱前比较均具有明显差异($p<0.05$)，见表 2。

表 2 不同海拔高度 HR、SaO_2 的变化

Table 2 Changes of HR and SaO_2 at different altitudes

	Plain	2000m	3000m	4500m
HR	71.58± 4.25	81.47± 3.92*	92.59± 4.38*	105.43± 3.28*
SaO_2	97.16± 0.67	95.22± 1.03	88.47± 1.566*	81.45± 1.25*

Note: *$P<0.05$, difference statistically significant.

2.3 进舱前、出舱后即刻血压值变化

进舱前受试者的血压值均在正常范围内，在低压舱内经历近 3 小时 " 上升 " 与 " 下降 " 海拔高度变化后，出舱后仅 8 例 (3.8%) 受试者的收缩压异常，两组相比没有统计学差异 ($p>0.05$)。见表 3。

表 3 进舱前、出舱后血压值变化比较

Table 3 Comparison of the blood pressure before and after entering the chamber

Blood pressure	Before entering the chamber	After entering the chamber
Systolic pressure	108.59± 12.41	110.25± 9.76
Diastolic pressure	70.17± 4.58	72.53± 5.67

3 讨论

长期居住平原个体由平原急进入高海拔地区(尤其是海拔 3000 m 以上时)，部分人群会发生以缺氧为主的一系列症状[12]，包括疲劳感、头痛、头晕、心慌、气短、胸闷、耳鸣(涨)、食欲减退、失眠等，称为急性高原反应(Acute mountain sickness，AMS)。轻度高原反应在休息后会得到缓解，重度高原反应可能危及生命[13]。有研究表明急性高原反应的发病与急进高原的方式、海拔高度、年龄、性别、种族、季节等有关，其发病率高达 57.2%，头昏、头痛及心悸等临床症状多且重，是影响官兵身体健康、造成非战斗减员、导致部队战斗力下降的重要因素[14,15]。

本研究所用大型复合低压舱能模拟不同海拔高度环境的功能，对 516 名健康官兵进行不同海拔高度环境自觉症状(如：头痛、头晕、气短、胸闷、恶心、耳涨、耳鸣、手足麻木等)测试，结果显示：① 海拔 4500 m 时，头晕 19 例(3.68%)、手足麻木 20 例 (3.88%)，" 下降 " 后均有好转，高原反应的发生率为 7.56%。大脑皮质代谢旺盛、耗氧量大、对低氧耐受性最低，上述变化与气压变化特点相一致。虽然出舱后大部分受试者血压值略高于进舱前血压值，但出舱后仅 14 例血压值在异常范围，两者相比没有统计学意义。本次调查对象未发生急性脑水肿及肺水肿，可能均与此次研究高海拔地域停留时间较短有关。② 海拔 2000 m 时，耳闷(涨)53 例(10.27%)、耳鸣 94 例(18.22%)，作了吞咽动作后在后续的 " 上升 " 和 " 下降 " 过程中均未出现。赵红艳等[16]研究中发现有 47.8%(75/157)的耳部不适症状，但真正达到耳气压功能不良诊断标准的只有 10 例，后期分析都存在不同程度的耳鼻疾患，且根据现场观察，主要是没有掌握好主动开放咽鼓管的动作要领。本研究中，上述耳部不适症状的发生率明显减低，分析原因可能是由于：① 本研究低压舱 " 上升 " 与 " 下降 " 速率较慢，气压变化的冲击力相对减低；② 进低压舱前宣教工作中强调了消除紧张情绪，及时开放咽鼓管的重要性和动作要领。因此，为预防和降低由平原急进高原地区健康人员的耳气压不适和损伤，消除焦虑和紧张情绪，主动掌握开放咽鼓管动作要领极其重要，并能较大程度提高健康保障。

血氧饱和度(SaO_2)是血液中被氧结合的氧合血红蛋白容量占全部可结合血红蛋白容量的百分比，是反映机体供氧程度、氧转运能力、对低氧适应及氧气在血液中浓度的重要生理学指标[17-19]。低压性低氧及低 SaO_2 可刺激颈动脉窦和主动脉体化学感受器，出现心率增快及反射性呼吸加深、加快，使心排血量、肺泡通气量和动脉血氧分压增加，从而提高 SaO_2；心率与氧耗量呈明显正相关[20]。低压性低氧、低 SaO_2 还可刺激血儿茶酚胺、垂体加压素和肾上腺皮质激素分泌增加，肾素 - 血管紧张素 - 醛固酮系统活性增强。此外，舱内焦虑等情绪不稳定因素也可能引起交感神经兴奋，从而导致心率、血压、SaO_2 及 ECG 等出现变化，我们在此项测试前对受试者均进行了心理干预以尽可能的避免心理因素的影响。本研究与平原所测的血氧饱和度进行自身对照比较的结果显示：即使在安静状态下，随着海拔高度升高血氧饱和度呈现逐渐下降趋势，当海拔高度在 2000 m 时，血氧饱和度降低 1%-2%。而在海拔高度 3000 m，平均 SaO_2 也不低于 88.47%。然而，在 4500 m 海拔高度 SaO_2 突然下降，即从 88.47%降至 81.45%。本研究还显示随着海拔高度的不断增高受试者的心率逐渐加快，尤其是在海拔 4500 m 时，异常心率与平原环境、海拔 2000 m 及 3000 m 具有显著性差异。因此，高原反应主要出现在 4500 m 海拔高度，其发生率为 7.56%。有研究表明 3700 m 与 298 m 之间的高度差所产生的大气压差、氧分压差的影响不能在短时间内习服[21,22]，这也是高山反应的一系列综合征的关键所在[23,24]。

本次研究首次在低压复合舱内模拟不同海拔高度对长期生活在平原的健康官兵进行了高原环境的适应性测试和分析，

结果显示高原环境对机体的心率、血氧饱和度的影响随着海拔高度增加而明显，即使在安静状态下，机体的氧耗也明显增加。行军部队随着体力活动的增加，机体缺氧程度会更加严重，为了最大限度减少急进高原反应，应重视下列预防措施：① 做好高原心理宣传教育活动；② 预防上呼吸道感染，如有上呼吸道感染，应推迟进入高原的时间，并给予积极的治疗；③ 适应性运动锻炼(高原习服)：能增强心、肺功能，改善机体对氧的摄取、运输和利用，提高机体最大有氧能力。本研究中，39 例官兵发生高原反应，在测试后在低压舱内进行了习服训练，在随后的高原实地训练中未发生高原反应。此外，在今后的研究中应加大样本量、细化海拔高度、增加不同海拔高度停留时间及适当增加测试过程中人体运动量等方面深入开展此项研究工作，为进一步完善急进高原官兵适应性预测、制定合理习服方案以降低高原疾病发生率提供科学依据。

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