ISSN 2616-5783 Vol.6, Issue 24: 119-127, DOI: 10.25236/AJHSS.2023.062420

The Effect of High Altitude on Emotion and its Physiological Mechanism

Jing Fan*

School of Education, Tibet University, Lhasa, 850000, China
**Corresponding author*

Abstract: *Experienced emotional discomfort as negative, depressive mood increase and positive mood reduce has been observed after long-term exposure to high altitude (HA). Scientists have found it can be affected through sleep, however few studies found it to have no relations with sleep at high altitude, so this study intends to find out whether sleep quality play its role in emotion variation of long-term migrants to HA, and whether the oxygen-carrying capacity can influence the possible effect of sleep quality on emotions. Maximal oxygen uptake (VO_{2max}) was measured and the participants also completed questionnaires including Pittsburgh Sleep Quality Index (PSQI), Positive and Negative Affect Scale (PANAS), Patient Health Questionnaire-9 items (PHQ-9) and Generalized Anxiety Disorder Questionnaire (GAD-7). The analysis of 105 health participants, who resided at a high altitude (3,680m) for more than 2 years showed that sleep quality is associated with depression mood and VO_{2max} can moderate the relationship between them, with sleep can better influence depression within individuals with lower VO_{2max}. These results indicate that oxygen carrying capacity can influence emotion through sleep, offer insights of emotion intervention at HA.*

Keywords: *High altitude, Emotion, Sleep quality, Maximal oxygen uptake, Depression*

1. Introduction

Emotion variations is a common experience in people ascent to high altitude (HA). It has early been brought up in review from Bahrke and Shukitt-Hale [1] that HA causes disturbance in mood as individuals tend be more anxious and irritable early days when ascent to HA. Similar results were observed in participants' depressive mood, anger, fatigue at HA and vigor scored lower than it was at sea level[2]. Not only people without any physical training can experience variations in emotion, even trained aviation personnel had fatigue increased and vigor reduced at 3657.6 m[3].

Short exposure of HA cause changes in emotion due to maladjustment, meanwhile, studies have found long-term exposure to HA also have negative effects on emotion. People who stayed a year or longer and never leave HA to a lower altitude were more inclined to be irritable[1]. And these long-time staying individuals tends to have more negative changes, not only than sea level ones, also than short-term staying ones, indicating the longer someone stayed at HA, the more serious he or she would have impaired emotional states[4]. More seriously, HA caused chronic hypoxia has been found to associated with depressive symptom[5], individuals who lived at high altitude or moved from low to high altitude tend to have an increased risk of depressive symptoms, anxiety and even suicidal ideation and rates[6,7] and reoxygenate after hypoxia can improve nerve damage related to depression[8].

Many researches have been carried out to discover the reason why HA can influence emotions, as mood disturbance such as decrease in positive mood and increase in negative mood[9], depression and anxiety always come along with sleep problems[10,11] which also get affected by hypoxia[12], even for acclimatized individual there still exist negative effect on sleep[13]. And at HA, in researches from Aquino Lemos et al.[2] and Feng et al.[14], they found the changes in mood is in correlation with sleep condition. Impaired depressed mood, anger, fatigue, tension, vigor under hypoxia, were actually induced through impaired sleep due to insufficient oxygen caused obstructive sleep apnea[15]. However, a study conducted at Kunlun Station (4087 m) in Antarctica found that, the expeditioners' slow-wave sleep significantly reduced and apnea/hypopnea index together with and hypopnea index were markedly increased. The vigor did decrease, but it did not have any significant relationship with sleep parameters[16]. The inconsistence may due to different experiment environment, as the result indicates relations were all conducted at normobaric chamber simulated an altitude around 4500m, while the null relation came from experiment conducted at real hypobaric hypoxia condition with an altitude of 4078m. Besides, subjects

ISSN 2616-5783 Vol.6, Issue 24: 119-127, DOI: 10.25236/AJHSS.2023.062420

in the study reveals relations experienced acute hypoxia around only 24 hours, while ones in 4078m study exposure to the real HA for 2 weeks. Also, it can be seen that the number of subjects were small in these studies, and this may induce inaccurate conclusions.

Other studies go deeper on the road, they went to the physiological aspects and found the oxygen-sensitive brain plays a part in mood variations. Hypoxia can lead to neurophysiological damages, the VOlume of hippocampus will shrink, adverse changes of ventromedial prefrontal cortex will occur, amygdala can experience losses in gray matter[17] and all these are areas related to emotion regulation[18,19].

It's not hard to see that all these mechanisms start from results that induced by hypoxia, like the changes of hippocampus, to discover the mechanisms of occurrence of mood variation at HA, less start from hypoxia itself, like VO_{2max}, which is correlated with cerebral oxygenation[20,21], and they are combined to be called the oxygen-carrying capacity. Given the fact insufficiency oxygen in the environment cause less oxygen breathed in our body and the body itself would generate compensation responses to combat the toxic environment, and for the one who have stayed at HA for long terms, their body already developed some extent of acclimatized mechanism, ones with better acclimatized oxygen-carrying capacity, they may cope better in brain hypoxia, less damages can happen and thus have better mood state. Besides, better oxygen-carrying capacity may also come along with better sleep quality as it means more oxygen in the system and the risk for problems in sleep decreases. Therefore, this study tends to discover whether, sleep quality is associated with mood in the acclimatized migrants at HA, oxygen-carrying capacity can influence emotion and sleep quality, and oxygen-carrying capacity and sleep quality can join to construct the causality relationship.

2. Method

2.1. Participants

We recruited 144 male participants from an university located at HA. All of the subjects have stayed at HA (3, 680 m) more than 2 years, and their birthplace are all below 1500 m. They never left HA for long-term except school holiday since their admission to University. Test time was the most recent arrival at high altitude for more than 2 months. All Participants were of good health, no addiction of alcohol nor cigarettes. All the subjects were informed the details of the experiment and signed a consent in their own will. The study followed the guidelines of the Declaration of Helsinki and was approved by the local government. Although 144 were recruited, only 126 participants completed the whole experiment. 6 were excluded for having data out of 3±SD, so, a total of 120 participants' data were taken into analyze.

2.2. Procedure

During the whole experiment, the subjects visited the laboratory twice. During the first time they were also asked to completed a series of questionnaires including PSQI, PANAS, PHQ-9 and GAD-7. On the second visit, they were guided to finish the cardiopulmonary exercise testing to assess their VO_2max.

2.3. Measures and Materials

2.3.1. Questionnaires

The questionnaires containing: basic information of themselves (age, height, weight, BMI), emotional parameters (PANAS, PHQ-9, GAD-7) and sleep quality (PSQI).

The Chinese version of Positive and Negative Affect Scale (PANAS) is a scale constituted with 20 items, including two factors, positive affect (PA) and negative affect (NA), each was assessed with 10 items. All items were rated on 5-point scales (1 = not at all, 5 = very much).

Patient Health Questionnaire-9 items (PHQ-9) was developed from the PRIME-MD, consists of nine items to self-rate depression during the previous 2 weeks. All items were rated on 4-point scales (0 = not at all, 3 = almost everyday). The Chinese version has been tested of good reliability and validity.

Generalized Anxiety Disorder Questionnaire (GAD-7) is a seven-item, self-report questionnaire designed to assess the subject' s anxiety status during the previous 2 weeks. All items were rated on 4-point scales (0 = not at all, 3 = almost everyday) and the Chinese version of this questionnaire has been found to have adequate reliability and validity.

ISSN 2616-5783 Vol.6, Issue 24: 119-127, DOI: 10.25236/AJHSS.2023.062420

Pittsburgh sleep quality Index (PSQI), a self-report questionnaire made up of 19 items, which combines to form seven component of sleep quality, including subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, sleep medication use, and daytime dysfunction. Each component score can range from 0 to 3. A total score of seven component were added up to be the finally analysis data in this study. The Chinese version of PSQI has received recognition with reliability and validation.

2.3.2. Cardiopulmonary Exercise Testing

VO_{2max} were evaluated though cardiopulmonary exercise testing. Before pedaling, participants were asked to sit quietly on the bicycle ergometer (EC3000e, Ergoline GmbH, Bitz, Germany, www.eergoline.com) for one minute and then they pedaled for one minute with a 30 W resistance to warm up. Subsequently, the resistance of the power bicycle increased by 30 W per minute, and the subject maintained the speed within 55-65 revolutions per minute (r/min) during the pedaling process. The participants were verbally encouraged to cycle until exhaustion, and when it was difficult for them to maintain the speed and the respiratory exchange ratio (RER) was greater than 1.1, we considered the participants to have reached a true state of exhaustion.The VO_{2max} measured at this point was considered to be the true VO_2max by gas analysis (METAKTZER® 3B, CORTEX Biophysik GmbH, Leipzig, Germany, www.cortex-medical.com) of the subject in hypobaric hypoxia. To ensure the safety of the subjects, their electrocardiography (custo cardio 100, custo med GmbH, Ottobrunn, Germany, www.customed.de) and SaO_2 (Model 3230 finger pulse oximeter with Bluetooth® Low Energy (LE) technology, Nonin Medical Inc., Plymouth, Minnesota, United States, www.nonin.com) were monitored continuously throughout the whole process and no abnormal signs were found.

2.3.3. Data Analysis

First, descriptive statistics for all the variables were analyzed using SPSS version 27.0 to describe and summarize their basic situation, and then Pearson' s correlation coefficients between the sleep quality, VO_{2max} and mood variables were calculated and Mann-whitney test was used to analyze the difference between two sleep quality groups. Second, linear regression was conducted for each mood parameters based on the correlation results. And last SPSS PROCESS 2.16.3 MODEL 1 has been used to analyze the moderate effect of VO_{2max}.

3. Result

3.1. Descriptives

Descriptive statistics of demographic information are in *Table 1*. Details of emotions, sleep quality and VO_{2max} are in *Table 2*.

Table 1: Demographic Profile.

Variables	Mean	*SD*	Maximum	Minimum
Age(years)	21.28	1.22	26.00	19.00
Height(m)	1.74	0.06	1.90	1.55
Weight(kg)	65.44	0.98	115.00	45.00
BMI	21.52	3.17	34.00	15.89

Note. BMI, Body Mass Index, SD, standard deviation.

Table 2: Mood and Sleep Profile.

Variables	Mean	*SD*	Maximum	Minimum
Positive affect	29.72	7.33	48.00	10.00
Negative affect	15.21	4.01	27.00	10.00
PHQ-9	3.79	2.90	13.00	0.00
GAD-7	2.58	2.52	11.00	0.00
PSQI	4.69	2.90	13.00	0.00
VO_{2max}	2.35	0.39	3.15	1.44

Note. SD, standard deviation, PHQ-9, Nine Items Questionnaire for Healthy People, GAD-7, Generalized Anxiety Disorder Questionnaire, PSQI, Pittsburgh Sleep Quality Index, VO_2max, maximum oxygen uptake.

ISSN 2616-5783 Vol.6, Issue 24: 119-127, DOI: 10.25236/AJHSS.2023.062420

3.2. Correlations Between Emotions and VO_{2max}

From correlations between variables in *Table 3*, it can be seen that, positive mood are significantly negatively correlated with two depressive mood (r_{PHQ-9} = -.30, p < .001; r_{GAD-7} = -.26, p < .01) apart from negative mood (r_N = .03, p > .05). And negative affect significantly positively correlates with PHQ-9 (r_{PHQ-9} = .51, p < .001) and GAD-7 (r_{GAD-7} = .66, p < .001) apart from positive affect (r_P = .03, p > .05). PSQI significantly correlates with all affect parameters (r_P= -.33, p < 0.001; r_N = .30, p < 0.001; r_{PHQ-9} = .56, p < .001; r_{GAD-7} = .41, p < .001).

Table 3: Correlations between variables.

Variables	P	N	PHQ-9	GAD-7	PSQI	VO_{2max}
P	—					
N	.03	—				
PHQ-9	-.31***	.51***	—			
GAD-7	-.26**	.66***	.72**	—		
PSQI	-.33***	.30***	.56***	.41***	—	
VO_{2max}	.10	-.08	-.09	-.10	.04	—

Note. * represents p<0.05, **represents p<0.01, ***represents p<0.001. P, Positive Affect, N, Negative Affect, PHQ-9, Nine Items Questionnaire for Healthy People, GAD-7, Generalized Anxiety Disorder Questionnaire, PSQI, Pittsburgh Sleep Quality Index, VO_{2max}, maximum oxygen uptake.

3.3. Difference in Emotions Between Two Sleep Groups

The subjects were divided into two groups according to their scores on PSQI (High quality group: PSQI <= 5, moderate quality group: 5 < PSQI <= 13), Mann-whitney test was used to examine the difference due to the abnormal distribution of the data. The results shows all mood parameters, depression, anxiety, positive affect and negative affect have significant difference between the two sleep groups, the mood of high quality group significantly exceed that of moderate group (see *Table 4*).

Table 4: Differences between mood in two PSQI groups.

	PHQ-9	GAD-7	PA	NA
Mann-Whitney U	643.000	781.500	1023.500	1027.000
Wilcoxon W	3803.000	3941.500	1884.500	4187.000
Z	-5.444	-4.713	-3.302	-3.293
Sig.	0.000	0.000	0.001	0.001

Note. PHQ-9, Nine Items Questionnaire for Healthy People, GAD-7, Generalized Anxiety Disorder Questionnaire, PA, Positive Affect, NA, Negative Affect. Linear regression models.

3.4. Linear Regression Models

Linear regression models were conducted with four mood parameters, in which depression, anxiety, positive affect and negative affect were dependent variables and PSQI was independent variable, with age, time living in HA and BMI as control variables. The results show that PSQI significantly predict all four mood parameters, even controlled for age, time living in HA and BMI. Sleep quality explains 34.8% variations in depression (R^2 = 0.348, ΔF = 45.753, p < 0.001), 19.6% variations in anxiety (R^2 = 0.348, ΔF = 19.663, p < 0.001), 13.6% variation in positive affect (R^2 = 0.137, ΔF = 8.674, p < 0.001) and 13.7% variation in negative affect (R^2 = 0.136, ΔF = 11.310, p < 0.001) (see *Table 5*).

Table 5: Results of four linear regression models.

Model for depression		Non-standardized coefficient		Standardized coefficient	*t*	Sig.	VIF
		B	Standard error	beta			
constant		13.708	4.928		1.812	0.073	
independent variable	PSQI	0.644	0.095	0.521	6.764	<0.001	1.045
control variable	Age	-0.192	0.195	-0.083	-0.984	0.327	1.260
	BMI	-0.051	0.069	-0.056	-0.738	0.462	1.006
	Time	-0.071	0.047	-0.130	-1.530	0.129	1.281

ISSN 2616-5783 Vol.6, Issue 24: 119-127, DOI: 10.25236/AJHSS.2023.062420

R^2				0.348			
ΔF				45.753			
p				<.001			
Model for anxiety		Non-standardized coefficient		Standardized coefficient	*t*	Sig.	VIF
		B	Standard error	beta			
constant		5.536	4.136		1.339	0.183	
independent variable	PSQI	0.408	0.092	0.379	4.434	<.001	1.045
control variable	Age	-0.102	0.189	-0.051	-0.541	0.589	1.260
	BMI	-0.051	0.069	-0.056	-0.738	0.462	1.006
	Time	-0.058	0.045	-0.121	-1.277	0.204	1.281
R^2				0.196			
ΔF				19.663			
p				<.001			
Model for PA		Non-standardized coefficient		Standardized coefficient	*t*	Sig.	VIF
		B	Standard error	beta			
constant		14.519	12.454		1.166	0.246	
independent variable	PSQI	-0.932	0.277	-0.298	-3.363	0.001	1.045
control variable	Age	0.757	0.569	0.130	1.331	0.186	1.260
	BMI	0.052	0.201	0.023	0.259	0.796	1.006
	Time	0.089	0.136	0.065	0.658	0.512	1.281
R^2				0.136			
ΔF				11.310			
p				.001			
Model for NA		Non-standardized coefficient		Standardized coefficient	*t*	Sig.	VIF
		B	Standard error	beta			
constant		16.193	6.804		2.380	0.019	
independent variable	PSQI	0.446	0.151	0.261	2.945	0.004	1.045
control variable	Age	0.123	0.311	0.038	0.395	0.693	1.260
	BMI	-0.092	0.110	-0.073	-0.837	0.404	1.006
	Time	-0.169	0.074	-0.224	-2.282	0.024	1.281
R^2				0.137			
ΔF				8.674			
p				.004			

Note. PSQI, Pittsburgh Sleep Quality Index, BMI, Body Mass Index, PA, Positive Affect, NA, Negative Affect.

3.5. Moderating Effect

Due to the reason that no relationship between VO_{2max} and any affect parameters were found, we tested whether moderation effect exist for VO_{2max}. SPSS PROCESS 2.16.3 MODEL 1 has been used to analyze the moderating effect of VO_{2max} between sleep and affect parameters, and found it indeed can moderate the effect between PSQI and PHQ-9. Findings in *Table 6* predicts a statistically significant positive variance (37.2 per cent) in PHQ-9 ($R^2 = 0.033$, $p < 0.01$). The beta coefficients of the model (see *Table 7*) manifests that, PSQI made it the strongest statistically significant contribution to the 37.2 per cent variance in PHQ-9 ($b = 0.602$, se = 0.070, $p < 0.001$). The interaction (int_1) of the moderating variable (VO_{2max}) to the predictive relation between PSQI and PHQ-9 is statistically significant ($b = -0.517$, se = 0.154, $p < 0.01$). This signifies that VO_{2max} negatively moderates the predictive relation between PSQI and PHQ-9.

And in *Table 8*, we see that VO_{2max} significantly moderates the predictive relation between PSQI and PHQ-9 (R^2change = 0.033, $p < 0.01$). Thus 3.32 per cent of the 37.16 per cent variance in PHQ-9 is ascribed to variations in VO_{2max}, so moderation is supported. The interaction effect shows that, under low VO_{2max} condition, individuals with low PSQI tend to have significant lower score on PHQ-9 and

ISSN 2616-5783 Vol.6, Issue 24: 119-127, DOI: 10.25236/AJHSS.2023.062420

individuals with high PSQI tend to have significant higher nine score. However, when under high VO_{2max} condition, it doesn't differ significantly whether the score of PSQI is high or low (see *Figure 1*).

Table 6: Model Summary.

R	*R-sq*	*MSE*	*F*	*df1*	*df2*	*p*
0.670	0.372	5.406	37.702	3.000	116.000	0.000

Note. MSE, mean square error.

Table 7: Moderating Effect of VO_{2max}.

Variables	*Aggression*					
	b	se	*t*	*p*	*LLCI*	*ULCI*
VO_{2max}	-0.938	0.505	-1.859	0.066	-1.937	0.061
PSQI	0.602	0.070	8.604	0.000	0.464	0.741
VO_{2max}*PSQI	-0.517	0.154	-3.354	0.001	-0.822	-0.212

Note. se, square error, LLCI, lower confidence interval, ULCI, upper confidence interval. PSQI, Pittsburgh sleep quality index, VO_{2max}, maximum oxygen uptake.

Table 8: R square Increase due to Interaction(s).

	R^2-chng	*F*	*df1*	*df2*	*p*
Int_1	0.033	11.250	1.000	116.000	0.001

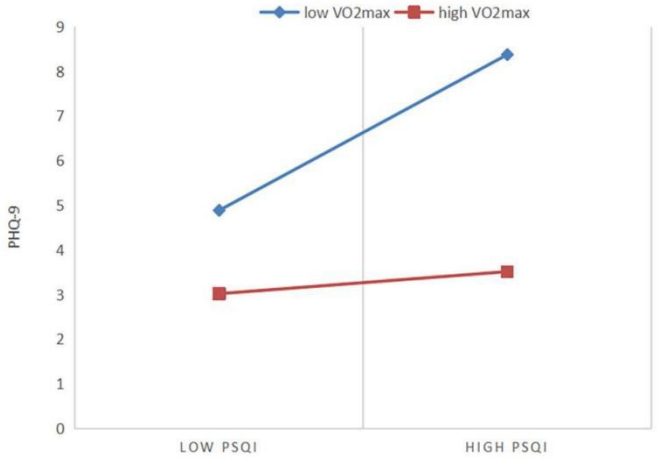

Figure 1: How VO_{2max} Affects the Relationship Between PSQI and PHQ-9.

Note. PSQI, Pittsburgh sleep quality index, VO_{2max}, maximum oxygen uptake, PHQ-9, nine items questionnaire for healthy people.

4. Discussion

The present study tends to find out whether oxygen-carrying capacity factors and sleep in these adapted individuals influence emotion, and how the influence construct the causality relationship in acclimatized individuals. The main findings could be summarized as follows. First, sleep quality is associated with mood within migrants at HA. Second, VO_{2max} moderates the relationship between sleep quality and depression.

4.1. The Effect of Sleep Quality on Mood Parameters

It has been widely accepted in sea level that problems in sleep always come along with emotional disturbance, loss of sleep cause activity variations in emotion related brain areas, such as amygdala and prefrontal cortex[22,23]. Sleep duration and sleep quality were significantly associated with emotional states, namely decrease in positive mood and increase in negative mood, such as anxiety[9]. In this study, the subjects were divided into high quality and moderate quality groups according to their scores on PSQI, and all mood parameter shows significant difference between two groups. Moreover, the results

ISSN 2616-5783 Vol.6, Issue 24: 119-127, DOI: 10.25236/AJHSS.2023.062420

of four linear regression models further proves the role of sleep in affecting moods, which are consistent with previous studies.

4.2. The Moderation Effect of VO2max on the Relationship Between Sleep and Depression

Value of VO_{2max} indicates the amount of available oxygen intake when the human body exercises at maximum intensity, reflecting one's aerobic capability and cardiorespiratory fitness level. Evidence has been found that elevated VO_{2max} occurs with higher level of cerebral oxygenation[20], besides, VO_{2max} can even elevate cerebral oxygen supply to the dorsolateral prefrontal cortex [21], an area related in depression[24]. So individual with higher VO_{2max} could cope better under hypoxia for higher cerebral oxygen in the brain. To our knowledge, no study yet explored the relationship between VO_{2max} and emotion at hypoxia. Meanwhile, at sea level, most researchers found there is no relationship between these two[25,26], very few have found VO_{2max} has negative correlation with subjective stress rating[27]. VO_{2max} is the same as erythrocyte when we consider the fact that, VO_{2max} may represents the amount of cerebral oxygen and low VO_{2max} indicates less oxygen in the brain, areas correlated with emotion like hippocampus, amygdala will experience damage[18,19]. So, when VO_{2max} gets altered due to hypoxia[28], so do the related areas and thus depression states.

Sleep is negatively correlated with positive affect, positively correlated with negative affect, depression and anxiety, meaning better sleep accompanies better emotional state, this suggest sleep may play its role in adjusting emotion, which is in consistent with previous studies[15]. VO_{2max}, the available oxygen intake when body exercise at maximum intensity, higher VO_{2max} indicates more oxygen-carrying when the body under hypoxia[20]. In our study, it's been found that sleep do have a role in depression, just the relationship is moderated by VO_{2max}. Acclimatized participants with higher VO_{2max} had lower level of depression, regardless of whether they slept well or not. However, depression scores were overall higher in participants with relatively low VO_{2max}, and sleep quality plays its role among low VO_{2max} individuals. Ones with good sleep have relatively lower depressive mood, while individuals with poor sleep scored relatively higher on depression. This indicates sleep can influence depressive mood when one has relatively low VO_{2max}, offers an explanation for the discrepancies between sleep and depression under HA hypoxia[15,16].

Although it is the first that finds a moderate effect of VO_{2max} between the relationship of sleep and depression, it does consist with previous finding that VO_{2max} doesn't have any correlations with emotional parameters[25] and the moderation role of VO_{2max} is reasonable, especially for participants during long-term exposure to HA. Because when the brain gets relatively more oxygen for operation for a continuous time, HA would lead to less brain function failures, such as hippocampus and amygdala, brain derived neurotrophic factor level (a mood protect factor), inflammation cytokines, neurotransmitters[17]. And since these factors all have influence on emotion [19,29], then individual with higher VO_{2max} can experience a more stable environment for mood states even under long term stress while the ones with lower VO_{2max} may experience more emotional variations as the long-term stress could cause more severe results for them.

4.3. Limitations and Prospects

This study found oxygen-carrying capacity have its effect on emotion through sleep quality, due to limitations in equipment, acquisition of structural and functional changes in brain areas like hippocampus and amygdala were missed in this study. Future study can take these emotion related areas into consideration, to discover whether the effect of sleep quality on emotion could through hippocampus or amygdala, and what's the interaction between brain functions and oxygen carrying capacity. Moreover, intended to control potential sex influence, this study only studied the possible effect of hypoxia on emotion on males, future study could explore whether the effect found in this study applies to females, adding together to provide a more comprehensive outlook with emotion at HA.

4.4. Conclusions

This study tends to explore whether oxygen-carrying capacity and sleep play their roles in emotional variation under HA hypoxia. And found that sleep quality influences emotion, besides, the relationship between sleep quality and depression can be moderated by VO_{2max}.

ISSN 2616-5783 Vol.6, Issue 24: 119-127, DOI: 10.25236/AJHSS.2023.062420

Acknowledgment

This research was supported by "High-level Talent Training Program" for Graduate students of Tibet University (grant number: 00061096).

References

[1] Bahrke, M. S., & Shukitt-Hale, B. (1993). Effects of Altitude on Mood, Behaviour and Cognitive Functioning. Sports Medicine, 16(2), 97–125. https://doi.org/10.2165/00007256-199316020-00003/

[2] Aquino Lemos, V., Antunes, H. K. M., Santos, R. V. T., Lira, F. S., Tufik, S., & Mello, M. T. (2012). High altitude exposure impairs sleep patterns, mood, and cognitive functions. Psychophysiology, 49(9), 1298–1306. https://doi.org/10.1111/j.1469-8986.2012.01411.x

[3] Legg, S., Gilbey, A., Hill, S., Raman, A., Dubray, A., Iremonger, G., & Mündel, T. (2016). Effects of mild hypoxia in aviation on mood and complex cognition. Applied Ergonomics, 53, 357–363. https://doi.org/10.1016/j.apergo.2015.10.002

[4] Gao, Y. X., Li, P., Jiang, C. H., Liu, C., Chen, Y., Chen, L., Ruan, H. Z., & Gao, Y. Q. (2014). Psychological and cognitive impairment of long-term migrators to high altitudes and the relationship to physiological and biochemical changes. European Journal of Neurology, 22(10), 1363–1369. https://doi.org/10.1111/ene.12507

[5] Zaeh, S., Miele, C. H., Putcha, N., Gilman, R. H., Miranda, J. J., Bernabe-Ortiz, A., Wise, R. A., & Checkley, W. (2016). Chronic respiratory disease and high altitude are associated with depressive symptoms in four diverse settings. The International Journal of Tuberculosis and Lung Disease, 20(9), 1263–1269. https://doi.org/10.5588/ijtld.15.0794

[6] Kious, B. M., Bakian, A., Zhao, J., Mickey, B., Guille, C., Renshaw, P., & Sen, S. (2019). Altitude and risk of depression and anxiety: findings from the intern health study. International Review of Psychiatry, 31(7–8), 637–645. https://doi.org/10.1080/09540261.2019.1586324

[7] Sabic, H., Kious, B., Boxer, D., Fitzgerald, C., Riley, C., Scholl, L., McGlade, E., Yurgelun-Todd, D., Renshaw, P. F., & Kondo, D. G. (2019). Effect of Altitude on Veteran Suicide Rates. High Altitude Medicine & Biology, 20(2), 171–177. https://doi.org/10.1089/ham.2018.0130

[8] Fan Wanlin, Wang Xin, He Yuxin et al. (2020) Effect and Mechanism of Chronic Intermittent Hypoxia on Depression in Rats with Obstructive Sleep Apnea Hypopnea Syndrome [J]. Chinese Journal of Clinical Psychology, 28(3), 445-449. DOI:10.16128/j.cnki.1005-3611.2020.03.003.

[9] Kamdar, B. B., Kaplan, K. A., Kezirian, E. J., & Dement, W. C. (2004). The impact of extended sleep on daytime alertness, vigilance, and mood. Sleep Medicine, 5(5), 441–448. https://doi.org/10.1016/j.sleep.2004.05.003

[10] Blaxton, J. M., Bergeman, C. S., Whitehead, B. R., Braun, M. E., & Payne, J. D. (2015). Relationships Among Nightly Sleep Quality, Daily Stress, and Daily Affect. The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, gbv060. https://doi.org/10.1093/geronb/gbv060

[11] Çelik, S., Genç, G., Kinetli, Y., Aşılıoğlı, M., Sarı, M., & Madenoğlu Kıvanç, M. (2016). Sleep problems, anxıety, depressıon and fatıgue on famıly members of adult intensıve care unıt patıents. International Journal of Nursing Practice, 22(5), 512–522. https://doi.org/10.1111/ijn.12451

[12] Bloch, K. E., Buenzli, J. C., Latshang, T. D., & Ulrich, S. (2015). Sleep at high altitude: guesses and facts. Journal of Applied Physiology, 119(12), 1466–1480. https://doi.org/10.1152/japplphysiol.00448.2015

[13] Sakamoto, R., Okumiya, K., Norboo, T., Tsering, N., Yamaguchi, T., Nose, M., Takeda, S., Tsukihara, T., Ishikawa, M., Nakajima, S., Wada, T., Fujisawa, M., Imai, H., Ishimoto, Y., Kimura, Y., Fukutomi, E., Chen, W., Otsuka, K., & Matsubayashi, K. (2017). Sleep quality among elderly high-altitude dwellers in Ladakh. Psychiatry Research, 249, 51–57. https://doi.org/10.1016/j.psychres.2016.12.043

[14] Feng, J., Wu, Q., Zhang, D., & Chen, B. Y. (2012). Hippocampal impairments are associated with intermittent hypoxia of obstructive sleep apnea. Chinese medical journal, 125 (04), 696-701. DOI:10.3760/cma.j.issn.0366-6999.2012.04.025.

[15] de Aquino-Lemos, V., Santos, R. V. T., Antunes, H. K. M., Lira, F. S., Luz Bittar, I. G., Caris, A. V., Tufik, S., & de Mello, M. T. (2016). Acute physical exercise under hypoxia improves sleep, mood and reaction time.Physiology & Behavior, 154, 90–99. https://doi.org/10.1016/j.physbeh.2015.10.028

[16] XU, C., LIU, S., KONG, Z., & CHEN, N. (2016). Sleep architecture, periodic breathing and mood disturbance of expeditioners at Kunlun Station (4087 m) in Antarctica. Advances in Polar Science.

[17] Zhao, F., Yang, J., & Cui, R. (2017). Effect of Hypoxic Injury in Mood Disorder. Neural Plasticity, 2017, 1–10. https://doi.org/10.1155/2017/6986983

[18] Erdi, P., Huhn, Z., & Kiss, T. (2005). Hippocampal theta rhythms from a computational perspective: code generation, mood regulation and navigation. Neural networks,18(9), 1202-1211.

ISSN 2616-5783 Vol.6, Issue 24: 119-127, DOI: 10.25236/AJHSS.2023.062420

https://doi.org/10.1016/j.neunet.2005.08.001.
[19] Wilson, M. H., Newman, S., & Imray, C. H. (2009). The cerebral effects of ascent to high altitudes. The Lancet Neurology, 8(2), 175–191. https://doi.org/10.1016/s1474-4422(09)70014-6
[20] MUKAIMOTO, T., UEDA, H., HAN, I. Y., SENBA, S., & OHNO, M. (2010). CHANGES IN CEREBRAL OXYGENATION DURING A SINGLE BOUT OF COMBINED CIRCUIT TRAINING. Japanese Journal of Physical Fitness and Sports Medicine, 59(5), 529–540. https://doi.org/10.7600/jspfsm.59.529
[21] Albinet, C. T., Mandrick, K., Bernard, P. L., Perrey, S., & Blain, H. (2014). Improved cerebral oxygenation response and executive performance as a function of cardiorespiratory fitness in older women: a fNIRS study. Frontiers in Aging Neuroscience, 6. https://doi.org/10.3389/fnagi.2014.00272
[22] Goldstein, A. N., & Walker, M. P. (2014). The Role of Sleep in Emotional Brain Function. Annual Review of Clinical Psychology, 10(1), 679–708. https://doi.org/10.1146/annurev-clinpsy-032813-153716
[23] Palmer, C. A., & Alfano, C. A. (2017). Sleep and emotion regulation: An organizing, integrative review. Sleep Medicine Reviews, 31, 6–16. https://doi.org/10.1016/j.smrv.2015.12.006
[24] Sibille, E., Morris, H. M., Kota, R. S., & Lewis, D. A. (2011). GABA-related transcripts in the dorsolateral prefrontal cortex in mood disorders. International Journal of Neuropsychopharmacology, 14(6), 721–734. https://doi.org/10.1017/s1461145710001616
[25] de Geus, E. J., van Doornen, L. J., & Orlebeke, J. F. (1993). Regular exercise and aerobic fitness in relation to psychological make-up and physiological stress reactivity. Psychosomatic Medicine, 55(4), 347–363. https://doi.org/10.1097/00006842-199307000-00003
[26] Osei-Tutu, K. B., & Campagna, P. D. (2005). The effects of short- vs. long-bout exercise on mood, VO2max., and percent body fat. Preventive Medicine, 40(1), 92–98. https://doi.org/10.1016/j.ypmed.2004.05.005
[27] Solianik, R., & Sujeta, A. (2018). Two-day fasting evokes stress, but does not affect mood, brain activity, cognitive, psychomotor, and motor performance in overweight women. Behavioural Brain Research, 338, 166–172. https://doi.org/10.1016/j.bbr.2017.10.028
[28] Martin, D., & O'Kroy, J. (1993). Effects of acute hypoxia on the VO2max of trained and untrained subjects. Journal of Sports Sciences, 11(1), 37–42. https://doi.org/10.1080/02640419308729961
[29] Bailey, D. M., Brugniaux, J. V., Filipponi, T., Marley, C. J., Stacey, B., Soria, R., Rimoldi, S. F., Cerny, D., Rexhaj, E., Pratali, L., Salmòn, C. S., Murillo Jáuregui, C., Villena, M., Smirl, J. D., Ogoh, S., Pietri, S., Scherrer, U., & Sartori, C. (2018). Exaggerated systemic oxidative-inflammatory-nitrosative stress in chronic mountain sickness is associated with cognitive decline and depression. The Journal of Physiology, 597(2), 611–629. https://doi.org/10.1113/jp276898