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Relationship between cardiorespiratory and executive functions in high-altitude hereditary Tibetans

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Abstract: *Higher cardiorespiratory fitness under acute hypoxic exposure improves cognitive function in individuals, while the effects of cardiorespiratory fitness on cognitive function in individuals under chronic hypoxic exposure and its mechanisms are not clear, so the purpose of this paper is to investigate whether cardiorespiratory fitness is related to cognitive function in individuals in the Tibetan population, and to further investigate the physiological mechanisms by which cardiorespiratory fitness affects cognitive function. It is of great theoretical and practical significance to study the relationship between cardiopulmonary function and cognitive function at high altitude. It is expected to further confirm the intrinsic connection between cardiorespiratory function and cerebral nerves as well as the physiological mechanism of plateau acclimatization at high altitude, providing more evidence for plateau acclimatization at high altitude.*

Keywords: *High altitude, Tibetan, Cardiopulmonary function, Executive function*

1. Introduction

Numerous studies have found that high-altitude, hypoxia environments can lead to impaired cognitive function in individuals, primarily in the form of slower reaction times, reduced psychomotor alertness, decreased sustained attention, and impaired executive function[1, 2]. When people are permanently exposed to hypobaric hypoxia environments, physiological and pathological changes occur, which can lead to impaired executive function. However, studies have found that improved cardiorespiratory fitness in individuals can have various positive effects on cognitive function[3, 4] . Cardiorespiratory fitness is critical for highlanders to acclimate to the hypoxic environment of the plateau, and a large Tibetan population that has lived on the Tibetan plateau for generations has been shown to have significantly better cardiorespiratory capacity than other high-altitude populations[5]. On this basis, the relationship between cardiopulmonary capacity and executive function in Tibetan individuals remains to be clarified. In this paper, we will elucidate the relationship between cardiopulmonary capacity and executive function and the corresponding physiological mechanisms in Tibetan individuals who have lived at high altitude for generations[1, 6].

2. Executive Functions of Tibetan Individuals

Executive functioning is an advanced cognitive ability, the coordination of various basic cognitive processes by an individual in the accomplishment of complex cognitive tasks, the fundamental purpose of which is to produce behaviors that are purposeful, coordinated, and orderly, and the essence of which is the regulation and control of other cognitive processes[7]. Behavioral executive function mainly includes three components: working memory, flexible switching and behavioral inhibition, of which behavioral inhibition is the core function[8, 9]. Zhu et al. showed that the cognitive level of students in high altitude areas was relatively lower than that of students in low altitude areas, postulated to be mainly driven by chronic hypoxia in high altitude areas. Long-term exposure to high altitude areas has been shown to negatively affect individuals' spatial working memory and significantly reduce their inhibitory control[10, 11]. Yan et al. found that repeated exposure to hypoxia over a long period of time (about 20 years) leads to a reduction in gray matter volume in the bilateral prefrontal lobes of the brain, directly impairing the neural basis of executive control functions[12]. Study has found that the hypobaric hypoxia environment at high altitude has a negative impact on executive functions, which restricts the work efficiency of plateau-dwelling populations and is also related to the development of the plateau economy and national defense[13].

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However, a lot of scholars have explored the cognitive functioning of individuals living at high altitude in the world, but the findings are not very consistent. Cassandra et al. found no negative sequelae of chronic hypoxia in adolescents born and living at an altitude of 3700 m and provided neurophysiological evidence of their cognitive and functional brain adaptations, while Ma et al.'s study of Tibetan seculars found that chronic hypoxia exposure only negatively affected their inhibition and information maintenance abilities[10, 14]. The reason for the inconsistent findings may be that when groups of people are exposed to high altitude hypoxia for long periods of time, the body develops a series of deeper physiological adaptations, including individual cardiorespiratory function. These adaptations may be important for the cognitive functioning of individuals. However, most high-altitude studies have focused on migrant populations and acute hypoxic exposure, and there are still gaps in the cognitive changes and physiological mechanisms induced by chronic hypoxia, so it is important to explore the cognitive functions of high-altitude habitats.

3. Cardiorespiratory fitness of Tibetans

Numerous studies have shown that cardiorespiratory fitness of Tibetan individuals at high altitude is superior to that of the rest of the population[15, 16]. In 2016 the American Heart Association recognized cardiorespiratory fitness as the fifth most important vital sign, in addition to respiration, temperature, pulse, and blood pressure, and considered it to be regularly assessed[17]. And one of the most important factors affecting the body's cardiorespiratory function is the partial pressure of oxygen. Hypobaric hypoxia causes changes in the individual oxygen transport system, ventilation, pulmonary diffusion and circulation at all levels. A previous study by Niu et al. compared Tibetan highlanders with Han Chinese lowlanders exposed to 3,680 meters for 27 months. They found no difference between maximal oxygen uptake of Tibetan and Han migrating Chinese, but higher Wpeak, interpreted as better total mechanical efficiency. The Tibetans had a higher work rate, suggesting that lifelong exposure or genetic background plays a role, at least in part, in high-altitude exercise capacity[18]. In contrast to Kyrgyz highlanders, Tibetans have been migrating to higher altitudes for longer and have a lower prevalence of chronic plateau diseases[19]. Tibetans are probably the best adapted population on the planet, reaching the lower limit of the reference value for maximum individual oxygen uptake at sea level[19]. Jun et al. found that the optimal adaptation to hypoxia in plateau-dwelling Tibetan populations may have been mediated by changes in immune cells, cytokines, and hypoxia-related genes during the evolution of Tibetan populations[20]. The high cardiorespiratory capacity of the plateau-dwelling Tibetan population on the Tibetan Plateau reflects a favorable physiological adaptation to the plateau environment, which may have a positive effect on the cognitive function of individuals.

Moreover, cardiorespiratory fitness is closely related to the level of psychological well-being, increasing an individual's level of cardiorespiratory fitness can effectively improve anxiety and depressive symptoms, as well as benefit executive functioning[21]. cardiorespiratory fitness was significantly correlated with inhibitory control and working memory, with greater cardiorespiratory fitness being associated with greater accuracy of responses in tasks that regulate inhibitory control and working memory demands[22]. Study has shown that cardiorespiratory fitness predicts response accuracy in flanker task inconsistency conditions[23], and higher levels of cardiorespiratory fitness also predict working memory performance in both 1-back and 2-back tasks[24]. Exercise has been shown to significantly improve cardiorespiratory fitness. There are two other explanations for the ability of exercise to improve executive function: the arousal level hypothesis, which suggests that short-duration aerobic exercise improves an individual's arousal level, increases metabolism, and increases blood flow to brain areas related to executive function, thereby improving executive function. The second is the catecholamine transmitter hypothesis, which suggests that short-duration aerobic exercise increases brain neuroendocrine levels, leading to changes in catecholamine transmitters in the brain, which improves executive function in individuals[25, 26].

4. Summary

By 2021, approximately 400 million people worldwide will live at altitudes above 1,500 meters and be exposed to chronic hypoxemia for life[19]. Study has found that severe hypoxia due to high altitude decreases oxygen delivery to brain tissue, leading to impairments in brain function and cognitive abilities, including executive function, attention, situational memory, and information processing[27]. At the same time, hypoxemia-induced systemic oxidative-inflammatory-nitrosative stress was found to be associated with accelerated cognitive decline in the highlanders[28]. Although the human body produces a series of

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adaptive responses to resist the damage of physical functions caused by hypoxia at high altitude, long-term exposure to high altitude will still lead to the damage of human physiology and brain functions. High altitude and low oxygen environment has adverse effects on the central nervous system of individuals, which can lead to neurological dysfunction and structural brain damage, and further lead to the decline of cognitive performance of individuals[29]. However, enhancing cardiorespiratory fitness has been shown to enhance cognitive function and prevent neurocognitive deficits, and it was further found that exercise training during exposure to acute hypoxia can improve cognitive function by enhancing cardiorespiratory endurance and thus cognitive performance[30, 31]. Su et al. found that acute aerobic exercise at an altitude of 3680 meters improved executive control of attention in young Han Chinese male transplants[32]. Aerobic exercise can increase the oxygen content of the blood in the prefrontal cortex and improve cognitive ability[33]. Aerobic exercise has a positive role in promoting individual cognitive function, which has been confirmed in delaying the decline of cognitive function, reducing the risk of Alzheimer's disease, promoting children's cognitive development and improving teenagers' academic performance[34-36].

The research on the effects of short-term exposure to high altitude on physiological function is a hot topic at present. However, there are few studies on the changes of physiological function in highland people affected by chronic hypoxia environment, High altitude acclimatization led to various physiological changes in the highlanders, especially stronger cardiorespiratory function. Zhang et al. compared the cardiorespiratory fitness of Chinese Tibetan adolescents with those of Han Chinese adolescents born and raised at high altitude and those of Chinese Han adolescents born at sea level, and found that the maximal oxygen uptake of Chinese Tibetan adolescents was higher than that of Chinese Han Chinese adolescents born and raised at high altitude[37]. However, the research reports on the relationship between better cardiorespiratory function and cognitive function in high altitude individuals have inconsistent conclusions. A survey of 1,093 Tibetan adolescents by Xia et al. found significant correlations between grip strength and memory executive function and cognitive flexibility in Tibetan adolescents at high altitude. Those with higher upper limb muscle strength had shorter reaction times, i.e., better executive functions[38]. Fan et al. found that muscle tissue oxygenation was lower in Tibetans at high-altitudes. This suggests that Tibetans prioritize brain tissue oxygenation at the expense of muscle tissue oxygenation.[39] Better aerobic capacity in Tibetans is interpreted as high muscle oxygen utilization, independent of individual cognitive function. Further research is needed to explore the relationship between cardiorespiratory and executive functions in Tibetans. High-altitude acclimatization leads to various physiological changes, especially in cardiorespiratory function, in sedentary individuals. This paper analyzes the perceived relationship between cardiorespiratory function and the corresponding physiological mechanisms in high-altitude habitats.

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Declaration of Competing Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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