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The Effect of Highland and Lowland Living on Cardiovascular Ability: a Literature Review

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Abstract: This study aims to review the literature related to the influence of living in highlands and lowlands on cardiovascular ability. Highlands, with an altitude of more than 2,500 meters above sea level, have unique environmental characteristics such as lower oxygen levels, lower air pressure, and cooler temperatures. In contrast, lowlands typically have more stable conditions and higher oxygen levels. These environmental differences are believed to have a significant impact on an individual's cardiovascular ability. In this literature review, we evaluated various studies comparing cardiovascular parameters such as aerobic capacity, VO2 max, resting heart rate, and other physiological adaptations between populations living in highlands and lowlands. The results of various studies show that individuals living at high altitudes tend to have better physiological adaptations in terms of oxygen use efficiency and higher aerobic capacity. This is due to the body's adaptation to chronic hypoxia, which increases red blood cell production and oxygen transport efficiency. However, there are also some higher cardiovascular challenges at high altitudes, such as an increased risk of pulmonary hypertension and heart disease. In contrast, low-lying populations generally show more stable cardiovascular parameters but are less adaptive to hypoxia conditions. In conclusion, living at high altitudes and lowlands exert different influences on cardiovascular ability, with each environment providing its own advantages and challenges. More research is needed to understand deeper adaptation mechanisms and their implications for long-term cardiovascular health.

Keywords: Aerobic Capacity; Cardiovascular; Lowland; Plateau; Physiological adaptation.

Introduction

Cardiovascular ability is one of the most important indicators of a person's health, reflecting the capacity of the circulatory system and lungs to distribute oxygen throughout the body during physical activity (Guo et al., 2024; Shi et al., 2024). This ability is influenced by a variety of factors, including genetics, lifestyle, and the environment in which they live. One aspect of the environment that has a significant influence is the height of the residence. Highlands and lowlands offer different environmental conditions, which can affect the cardiovascular abilities of individuals living in the area (Gao et al., 2022; D. Sun et al., 2023).

Plateaus, which are generally located more than 2,500 meters above sea level, have unique environmental characteristics. In these regions, oxygen levels are lower (hypoxia), air pressure is lower, and temperatures are cooler (Achebak et al., 2023; N. Chen et al., 2024; Tian et al., 2023). This condition forces the body to adapt in order to still be able to meet its oxygen needs. These adaptations can be in the form of increased production of red blood cells, changes in the efficiency of oxygen use, and modifications in lung and heart function. As a result of these adaptations, many studies show that people living in highlands tend to have better aerobic capacity and higher cardiovascular abilities compared to

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those living in lowlands (J. Chen et al., 2023; G. Li et al., 2022; Yuqin Zhang et al., 2023).

In contrast, lowlands, which are usually located at altitudes below 500 meters above sea level, offer more stable conditions with fairly high oxygen levels (Liang et al., 2023; Vincent et al., 2022). Residents in this region do not face adaptive pressure to hypoxia, so their cardiovascular function tends to be more stable but less adaptive to changes in oxygenation conditions. However, living in low-lying areas also carries its own risks, such as a higher prevalence of coronary heart disease due to a less active lifestyle and higher exposure to pollutants. By understanding the differences in cardiovascular adaptation between highland and lowland populations, we can develop better strategies to improve cardiovascular health in general (Chang et al., 2023; LI et al., 2023; Tao et al., 2023; Xu, Wei, et al., 2022).

Research on the effect of dwelling height on cardiovascular ability has grown rapidly in recent decades, combining multidisciplinary approaches from physiology, sports medicine, and epidemiology. Recent studies Z. Li et al., (2022); Liu et al., (2023); Wang et al., (2024); Zhu et al., (2024) showed that individuals living at high altitudes showed significant physiological adaptations such as increased hematocrit and higher aerobic capacity, which contributed to better efficiency of oxygen use. In addition, advanced techniques such as magnetic resonance imaging (MRI) and echocardiography have been used to study structural and functional changes in the heart and blood vessels in populations living at various altitudes. On the other hand, research in the lowlands has identified different cardiovascular health risks, including an increased incidence of coronary heart disease related to lifestyle and urban environments. The development of intervention methods such as intermittent hypoxia training is also a hot topic, aiming to mimic highland adaptations in lowland populations to improve cardiovascular health (A. Li et al., 2024; J. Wu et al., 2024). Penelitian terkini Okada et al., (2023); Psistaki et al., (2023) continue to seek to unravel the biological mechanisms underlying these differences and find ways to apply these findings in clinical and public health contexts.

This study offers a comprehensive approach that combines findings from previous studies to provide a comprehensive picture of the effects of living at high altitudes and low-altitudes on cardiovascular ability. The novelty of this review lies in mapping the specific physiological adaptations that occur in both types of environments, as well as the identification of health risks unique to each population. In addition, the review also explores the use of advanced technologies such as MRI and echocardiography to understand structural and functional changes in the cardiovascular system, which have not been widely discussed in the previous literature. This holistic approach allows for a deeper and integrated understanding of how the height of residence affects cardiovascular health (J. Li et al., 2023; Song et al., 2023).

The main contribution of this study is the provision of a comprehensive framework for researchers and health practitioners to understand the influence of altitude environment on cardiovascular ability (Requia, Vicedo-Cabrera, et al., 2023; Tsao et al., 2023). By combining data from various studies and the latest technologies, this research helps to identify specific adaptation mechanisms and health risks, so that it can be used as a basis for more effective health interventions. In addition, this review opens up opportunities for the development of intermittent hypoxia training methods for low-lying populations, potentially increasing their cardiovascular capacity by mimicking high-altitude conditions. This research can also influence public health policy by providing evidence-based recommendations on lifestyles and appropriate interventions for people at various altitudes.

Method

This study uses a qualitative descriptive research model that is a literature study that uses various literature reviews in strengthening research analysis. This research begins by collecting several literatures, then reviewing several important terms in the research, then collecting relevant research literature, then conducting analysis based on all the literature that has been obtained by compiling a discussion, then compiling conclusions based on the results that have been analyzed and making suggestions based on the conclusions obtained.

The data used in this study is using secondary data. Sugiyono, (2015) states that secondary data is data that is taken indirectly that can provide information to data collectors. The data sources obtained are in the form of original scientific reports derived from published scientific articles and journals that have been accredited and indexed, both print and non-print which are interrelated in the model of implementing blended learning in physical education and sports.

The data collection method used in this study is the documentation method. The documentation method is a method of collecting data by digging and searching for data from the literature related to what is in the formulation of the problem. The data that has been obtained from various literature is then collected as a single document that will be used in answering the problems that have been formulated.

The article search technique in this study is through Mendeley web access, google scholar, and scinece direct as well as on access to other journals with the keywords The Influence of Living in Highlands and Lowlands on Cardiovascular Cardiovascular Ability, Highlands, Lowlands, Aerobic Capacity, Physiological Adaptation. Articles or journals that meet the criteria are then taken for further analysis and a summary of the journal including the name of the researcher, the year of publication of the journal, the design of the study, the purpose of the research, samples, instruments, and a summary of the results or findings. The summary of the research journal is included in a table sorted according to the alphabet and year of publication of the journal and in accordance with the format mentioned above. This review literature uses literature that can be accessed in fulltext in pdf format and scholarly (peer reviewed Journal). To further clarify the abstrack and full test, the journal is read and observed. The summary of the journal is analyzed on the content contained in the research objectives and research results/findings. Analysis method used to analyze journal content.

Result and Discussion

This review literature review was conducted to determine the Effect of Living in Highlands and Lowlands on Cardiovascular Ability. The collected literature was analyzed with a critical apprasial table to answer the measurement objectives compared to the results of simple measurements. There are as many as 5 literatures that discuss the Influence of Living in Highlands and Lowlands on Cardiovascular Ability, all of these journals are journals that are international journals that are searched on the Google Scholar, Mendeley, Science direct.com portal by typing the keywords "cardiovascular, highland, lowland, aerobic capacity, physiological adaptation" which is then analyzed using critical apparsial analysis to analyze from the core journals, as well as the results or findings of these journals. The following is a table of critical apparsial analysis from 5 journals.

Table 1. Literature Review Summary of Results

Researcher	Research title	Research results
(Bafirman et al., 2023)	Comparison of vo2max capacity and lung vital capacity of junior high school students: highlands and lowlands	Basedon the results of data processing, it was found 1) there was a significant difference between VO2Max of juniorhigh school students in highland areas and lowland areas p-value (2-tailed) of p=0.026 (<0.05). 2) There is asignificant difference between the vital lung capacity of junior high school students in highland areas andlowland areas with p-value (2-tailed) of p=0.000 (<0.05). It was concluded that VO2Max capacity and lungvital capacity were better in junior high school students living in the highlands than living in the lowlands inlarge areas with an altitude of 542 meters above undersea level
(Mallet et al., 2021)	Impact of High Altitude on Cardiovascular Health: Current Perspectives	This review aims to interpret epidemiological observations in high-altitude populations; present and discuss cardiovascular responses to acute and subacute high-altitude exposure in general and more specifically in people with preexisting cardiovascular diseases; the relations between cardiovascular pathologies and neurodegenerative diseases at altitude; the effects of high-altitude exercise; and the putative cardioprotective mechanisms of hypobaric hypoxia.
(Jin et al., 2023)	Association between ambient temperature and cardiovascular diseases related hospital admissions in Lanzhou, China	In the stratified analysis, cold decreased RR significantly in female and ≥65 years, whereas heat increased it more obviously in male and ≥65 years. Ambient temperature and CVD admissions were positively associated, with the harvesting effect. Our findings demonstrate the adaption of residents in Lanzhou to cold temperature. Public and environmental policies and measures aimed at moderate heat may minimize CVD burden effectively.
(Xu, Shi, et al., 2022)	Cause-specific cardiovascular disease mortality attributable to ambient temperature: A time-stratified case-crossover study in Jiangsu province, China	Exposure to ambient temperature was significantly associated with increased risk of cause-specific CVD mortality. The burden of CVD mortality attributable to non-optimum temperature was substantial especially in older and widowed adults, and significantly varied across specific types of CVD.
(Pan et al., 2023)	Association between ambient temperature and cause-specific cardiovascular disease admissions in Japan: A nationwide study	Substantial evidence suggests that non-optimal temperatures can increase the risk of cardiovascular disease (CVD) mortality and morbidity; however, limited studies have reported inconsistent results for hospital admissions depending on study locations, which also lack national-level investigations on cause-specific CVDs.

From the results of the literature study of 5 articles that have been reviewed and explained, the impact of the difference in environmental conditions between highlands and lowlands has a significant impact on the cardiovascular ability of individuals living in each area (H. Chen et al., 2022). At high altitudes, lower air pressure leads to hypoxia, which is a condition in which the body receives less oxygen compared to sea level levels. To overcome this hypoxia, the body undergoes various physiological adaptations such as increased production of red blood cells and hemoglobin, which play an important role in increasing the oxygenation capacity of the blood. In addition, increased lung volume and capillary efficiency in muscle tissue were also found in highland populations, all of which contributed to increased aerobic capacity and cardiovascular performance (Ying Zhang et al., 2022).

In contrast, people living in lowlands do not face the same adaptation pressures to hypoxia (Politis et al., 2024; R. Zhu et al., 2024). However, they tend to show more stable cardiovascular parameters due to the absence of the need for extreme physiological adaptations. Nonetheless, lifestyle and environmental factors such as air pollution and low-lying diets can negatively affect cardiovascular health. For example, an increased incidence of coronary heart disease and hypertension is more commonly found in urban lowland areas, which are often associated with less physical activity and unhealthy diets. Therefore, although cardiovascular ability may be more stable, the risk of cardiovascular disease remains high due to lifestyle factors.

In addition, studies have shown that according to Gouveia et al., (2024); Y. Sun et al., (2023) that intermittent hypoxia-based interventions, in which low-lying individuals are periodically trained in low-oxygen conditions, can mimic some of the physiological adaptations found in high-altitude populations. This method shows potential to improve cardiovascular capacity and physical performance in individuals living in lowlands. More research is needed to optimize hypoxia training protocols and understand their implications for long-term health (Rastegar et al., 2024; Xi et al., 2022). Thus, the combination of natural adaptations at high altitudes and artificial interventions at low altitudes offers new insights in efforts to improve cardiovascular health at different residential altitudes (Frampton et al., 2022).

From the literature analysis carried out, it is clear that the physiological adaptations experienced by the highland population provide some significant cardiovascular advantages (K. Wu et al., 2022; X. Zhu et al., 2023). Increased production of red blood cells and hemoglobin in response to hypoxia improves the blood's ability to transport oxygen, which is essential for aerobic performance (Hu et al., 2024; Requia, Alahmad, et al., 2023). In addition, increased lung volume and capillary efficiency improve gas exchange and oxygen delivery to muscle tissue. This adaptation not only increases aerobic capacity but also increases the body's endurance and efficiency in using oxygen, which is very useful for intensive physical activity and in low-oxygen conditions (J. Zhang et al., 2024; Yi Zhang et al., 2023). This suggests that the chronic hypoxia environment at high altitudes can spur the body to develop biological mechanisms that allow for more efficient utilization of oxygen.

Conversely, although low-lying people may not have the same extreme physiological adaptations, they still have unique cardiovascular risks related to their lifestyle and environment (Seah et al., 2022; Ugalde-Resano et al., 2022). Lack of exposure to hypoxia did not promote an increase in hematocrit or blood oxygenation capacity, so the potential for an increase in aerobic capacity was lower compared to that of highland populations. However, the risk of cardiovascular diseases such as hypertension, coronary heart disease, and obesity is higher in the lowlands, often triggered by lifestyle factors such as poor diet, lack of physical activity, and pollution exposure. Interventions such as intermittent hypoxia training offer a potential solution by mimicking some of the physiological adaptations of the highlands, providing an opportunity to improve cardiovascular health in the lowlands. Therefore, understanding these differences in depth can help in designing more effective health interventions, tailored to the environmental conditions and lifestyles of people at different altitudes.

Conclusion

This study comprehensively revealed that living in highlands and lowlands has a significant and different influence on an individual's cardiovascular ability. Highland dwellers show superior physiological adaptations, such as increased red blood cell production and oxygen use efficiency, which increase aerobic capacity and endurance. In contrast, low-lying populations, despite having more stable cardiovascular parameters, face a higher risk of heart disease due to lifestyle and environmental factors. Thus, understanding these differences not only provides deep insights into cardiovascular adaptation but also opens up opportunities to develop more precise and effective health interventions, both through natural approaches and artificial interventions such as intermittent hypoxia training. This study emphasizes the importance of adjusting health strategies based on the conditions of the living environment to optimally improve cardiovascular health.

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Author Contributions
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Conflicts of Interest
Regarding this study, the author declares that there is no conflict of interest.

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