EFFECTS OF OUTDOOR VOLLEYBALL EXERCISE ON CARDIORESPIRATORY FUNCTION UNDER A HEAVY HAZE ENVIRONMENT

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ABSTRACT

Haze has been one of the originators of the impact on human health. It is noteworthy that all functions of the human body can decline or even fail in a heavy haze environment. In this paper, the environmental monitoring website was used to count the data of meteorological and other natural factors as well as socio-economic influencing factors in the target cities over the past year. On this basis, the spatial and temporal distribution patterns of heavy haze weather were analyzed and studied. For the 100 volunteers who had been exposed to heavy haze pollution for a long time, the physical activity time of volleyball was classified into four levels using the quadratic method. Apart from that, a mixed linear model with fixed and random effects was constructed to explore the effects on cardiorespiratory fitness after outdoor volleyball exercise under a heavy haze environment. According to the model analysis results, the outdoor volleyball exercise had a significant interaction effect on pulmonary ventilation function in men only. Moreover, volleyball could be beneficial to the target group when the physical activity had not yet reached the level of high-level volleyball physical activity. This resulted in an improvement of 0.2L, 0.04L, 1.19%, and 0.03L in their pulmonary ventilation function indexes, respectively. However, the negative effects of a heavy haze environment were heavier after reaching a high-level degree. In addition, the indicator kept decreasing, from 2.04L, 1.13L, 63.63%, 1.99L to 1.98L, 1.04L, 60.78%, and 1.83L, respectively.

KEYWORDS

Heavy haze; Outdoor environment; Volleyball; Human cardiorespiratory fitness; Physical activity level.

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1. INTRODUCTION

Haze is one of the weather phenomena of atmospheric pollution. If there is haze in the air, the air at this time contains a large amount of particulate matter, such as dust, soot, and dust. These substances make the air more turbid and the visibility level decreases with it, usually below 10 km [1-3]. There is a clear difference between fog and haze. Since haze particles are generally distributed in the air in a uniform form, the visibility in the air is very uniform when haze weather occurs. There is a clear difference between fog and haze, as haze particles are generally distributed in the air in a uniform form, so when haze weather occurs, the visibility in the air is very uniform. Haze contains many particles that are harmful to the human body, and some of them can enter the interior of the human body directly through the respiratory tract and cause serious damage to the human body [4-5]. Haze contains mainly sulfuric acid-like substances and carbon particles. Since it contains more visible light and the scattering wavelength of these visible lights is longer, the haze seen by the naked eye is generally orange or yellow [6-8]. Most cities in China generally show an orange-gray color when the air appears polluted, because black carbon is one of the main atmospheric pollutants in China [9]. Unlike the effects caused by other severe weather, when haze occurs it is characterized by a wide area and long duration. Many harmful substances are contained in the air, especially absorbable particles that can enter the human body through the respiratory tract and can cause incalculable damage to humans [10-11].

With the rapid development of China's economy and technological reform, the size of China's economy has been expanding over time. At the same time, air pollution in China is increasing, especially in economically and industrially developed cities, and the number of accidents and deteriorations caused by air pollution is increasing [12-13]. In the original lexicon, "haze" was a natural phenomenon, which is a substance that causes an obstacle to visual distance [14-16]. Nowadays, it has evolved to be caused mainly by the pollution of the environment by human economic activities, so the protection of the environment should receive more and more attention [17].

With rapid economic development and rising national living standards, people have begun to pursue a healthy lifestyle, and more and more people are joining the ranks of exercise [18]. Due to the large population in China, indoor exercise places cannot meet the needs of the public, and outdoor exercise has become an important way for people to participate in exercise [19]. However, due to the aggravation of air pollution in recent years, whether outdoor exercise should be adhered to under air pollution conditions has led to extensive discussions [20-22]. The study of air pollution and exercise was first started by developed Western countries, however, with the rapid development of industrialization, air pollution in China has become increasingly serious and the exercise population has gradually increased. Therefore, it is necessary to investigate the relationship between air pollution and the physiological health of the outdoor exercise population in China [23-25].

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The effects of air pollution on the physical and mental health of exercising populations have received international attention. For example: the literature [26] investigated temporal changes in particulate matter exposure along urban waterfront trails. A recreational choice framework was used to examine the impact of visitor perceptions of air quality and health benefits on track usage. The average air quality during the collection period was "good" to "moderate". The results suggest that these empirical factors may influence leisure choice depending on other factors, such as significance. The literature [27] measured exertional spirometry and exertional expiratory volume in 1 second outdoors before and after two trials of 3200 m running. Subjective ratings of respiratory distress were quantified after exercise using a 10 cm visual analog scale. Results validation: PM2.5 differed ≥18 μg/m3 between trials. 3200 m run time did not differ between trials despite feeling more respiratory discomfort during the bad air trial compared to the good air trial. There was no significant difference in post-exercise exertional spirometry between low and high PM2.5 conditions. Ten healthy males were selected in the literature [28] and completed two 90-minute constant load cycling trials under trap or filtered air conditions. Metabolic profiles were evaluated using non-targeted analysis based on nuclear magnetic resonance metabolomics. Results showed that metabolic pathways for glycine and serine metabolism were altered during 30 minutes of exercise under TRAP conditions. Arginine and proline metabolism at 60 minutes of exercise; glycolysis at 90 minutes of exercise. The literature [29] was aimed at 80 non-smoking participants aged 16 to 21 years, using a bicycle ergometer for incremental testing, while measuring heart rate and ventilation per minute. A linear mixed model was constructed using data obtained from the cardiorespiratory exercise test. Ten individuals were randomly selected as an external validation group to assess predictive performance using an eight-fold cross-validation procedure. During the cardiorespiratory exercise test, air pollution concentrations were monitored and inhalation loads were calculated. Results validation: The median difference between ventilation measurements and predictions was 0.3 L/min and the difference between inhalation load based on fit and measurements was 0.0 to 0.3μg in all participants. In the literature [30], 30 healthy young men were invited to perform two separate 15-minute submaximal exercise trials on a cycle ergometer. The trials measured blood pressure, pulse oximetry, spirometry, and exhaled nitric oxide fraction. The results validated that the decrease in 1-second exertional expiratory volume/FVC following exercise at high air pollutant concentrations during the exposure test was significantly and negatively correlated with SO2, PM10, and PM2.5 concentrations. By collating and summarizing the current literature, the effects of air pollution on exercise were mainly studied in two aspects: the effects of air pollution on the physical and mental health of the outdoor exercise population, and the effects of air pollution on outdoor exercise behavior. However, most of the studies were conducted mainly on the hazards of air pollution on the physiological health of the exercise population.

When outdoor exercise is performed under air pollution conditions, it can lead to increased disease prevalence and reduced life expectancy once lung air pollutant deposition increases to a certain level. For this reason, in this paper, 100 volunteers

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were selected from regions with a more severe spatial and temporal distribution of haze, and the level of physical activity generated by outdoor volleyball exercise was grouped according to their cardiorespiratory fitness and total daily metabolic equivalent values using a quadratic approach. Based on a simple linear model, the effects of outdoor volleyball exercise on the heart and lungs in a heavy haze environment are discussed by combining continuous variables such as systolic blood pressure and diastolic blood pressure with categorical variables such as volleyball activity level. The purpose of the study was to increase awareness of cardiorespiratory health and physical activity in volleyball and to increase the importance of physical activity and the benefits of changing exercise patterns in a heavy haze environment.

2. CHARACTERISTICS OF SPATIAL AND TEMPORAL DISTRIBUTION OF HEAVY HAZE IN THE STUDY AREA

On the environmental monitoring website, the data of natural and, socio-economic influencing factors of the target city in the last year were counted to analyze and study the spatial and temporal distribution pattern of heavy haze weather [31-33]. The spatial distribution state of particulate matter concentrations in a year was analyzed based on the PM2.5 and PM10 concentrations counted in the city throughout the year [34-35]. Figure 1 is made based on the quarterly averages of PM2.5 and PM10 concentrations of polluting particulate matter at eight monitoring sites in the city throughout the year related to heavy haze weather, using spatial interpolation with GIS technology. This figure gives the spatial distribution of PM2.5 and PM10 concentration values of particulate matter in the target city for the last year, respectively [36].

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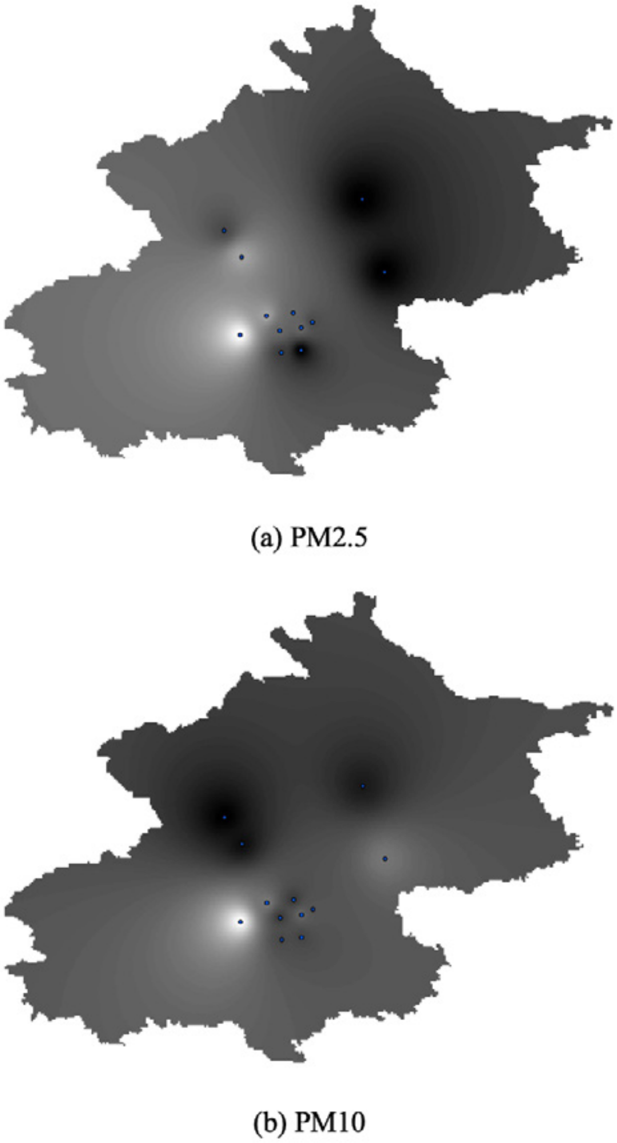

Figure 1. Spatial interpolation distribution of pollutants in different seasons under heavy haze environment

As can be seen from Figure 1, the concentration values of particulate matter in the same quarter have an uneven regional distribution in terms of spatial distribution. According to the current land use situation of the city, the concentration of polluting particulate matter decreases gradually from the city center to the outskirts of the city in a scattering pattern. The distribution of the same polluting particulate matter varies from season to season, with generally lower overall concentration values in spring and summer, and generally higher overall concentrations in autumn and winter. The generally low concentration values of these spring and summer pollutants are mainly influenced by meteorological conditions. Due to increased precipitation in spring and summer, rain has a purifying effect on pollutants, while high temperatures and high humidity in summer are also conducive to the diffusion of pollutants. And the overall concentration of polluting particulate matter is generally higher in autumn and winter, mainly due to the influence of pollution sources, and factors such as fireworks during

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the Spring Festival and dust storms in the north. Spatially, the overall pollution particulate concentration values are gradually decreasing from the city center to the outskirts of the city in a scattering pattern. The distribution trend of PM2.5 and PM10 concentration values of different pollutants varies with the quarter. However, their distribution states are similar in the same quarter, while remaining similar to the distribution states of haze. In summary, the pollutant particulate matter has uneven distribution in space, the more economically developed the region, the higher the pollutant concentration value, and vice versa, lower. Temporally, influenced by various factors such as pollution sources and meteorological elements, there are significant differences between different months and concentrations, showing cyclical changes, and mainly concentrated in the autumn and winter seasons.

3. RESEARCH ON THE EFFECT OF OUTDOOR VOLLEYBALL ON HUMAN CARDIORESPIRATORY FITNESS

3.1. SELECTION OF RESEARCH OBJECTIVES

To improve the accuracy of the research results, 100 volunteers aged 18 years or older who participated in the survey in the study area were selected as valid samples to explore the effect of outdoor volleyball exercise on human cardiorespiratory fitness in the region with long-term heavy haze pollution. Among them, the data of volunteers with missing data during the survey were excluded. The mean age of all study subjects was 28.94±0.55 years, including 64 males with a mean age of 32.11±0.38 years and 36 females with a mean age of 24.95±0.87 years. Physical activity level subgroups were classified according to the quartiles of the total daily metabolic equivalent values of the 100 study subjects included. The daily metabolic equivalents of the study subjects were solved by the following equation.

$$MET = \sum \left(MET_n \times H_n\right) \tag{1}$$

Where MET_n is the metabolic equivalent of volleyball exercise, and H_n is the average daily volleyball time. Figure 2(a) shows that body mass index, 1-second expiratory volume with force, volume-to-lung capacity ratio, maximum expiratory flow, and maximum oxygen uptake were greater in men than in women in the total study population. Quiet heart rate was greater in females than in males. The group sizes of males and females in different physical activity levels after volleyball exercise outdoors are shown in Figure 2(b). Due to the large range of physical activity time data in volleyball, the quartile method was used to classify the physical activity time in volleyball into four different classes. Those with average daily physical activity time of 0 to 69.4 minutes were classified as low grade, those with average daily physical activity time of 69.4 minutes to 110.5 minutes were classified as medium grade, those with average daily physical activity time of 110.5 minutes to 153.1 minutes were

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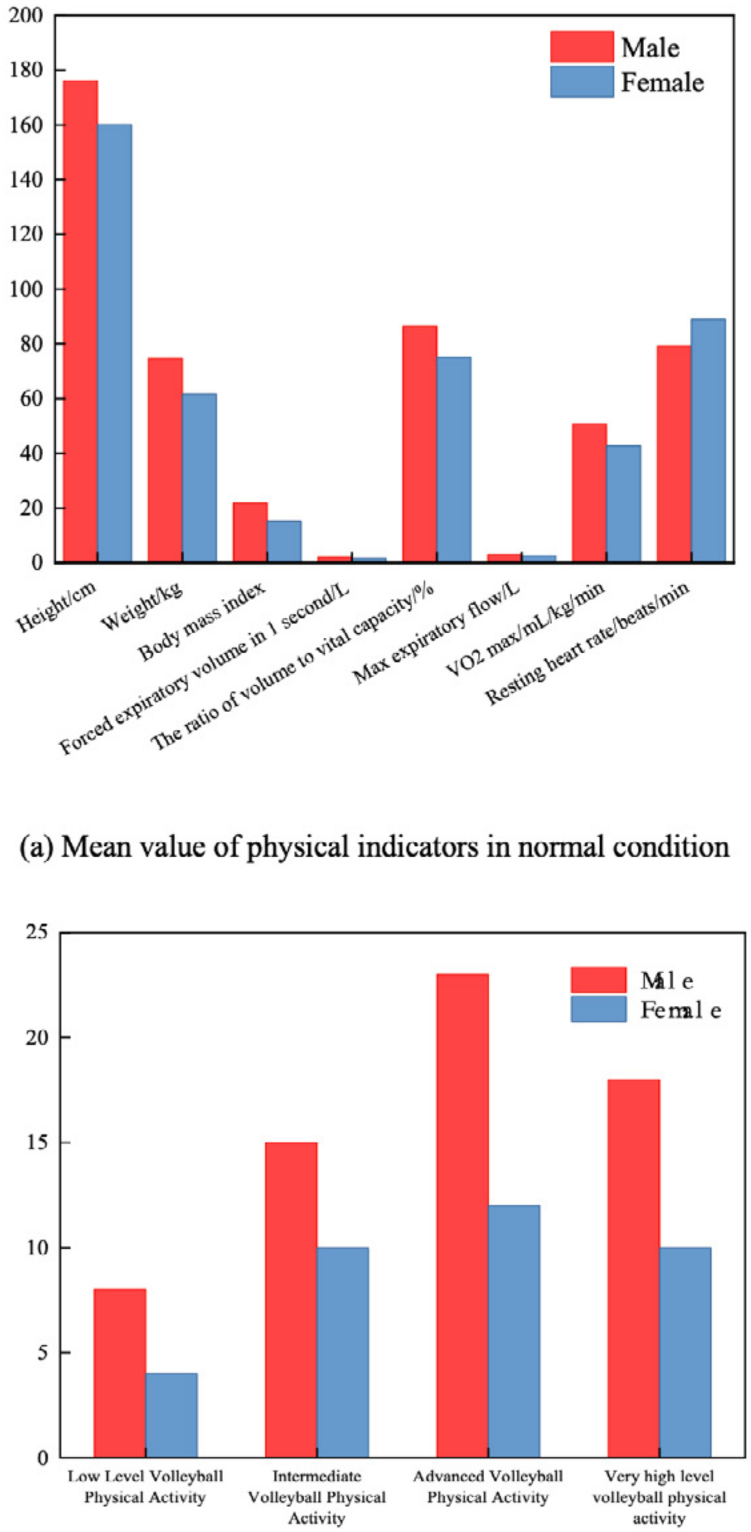
classified as high grade, and those with average daily physical activity time of 153.1 minutes or more were classified as very high grade [37].



(a) Mean value of physical indicators in normal condition

(b) Number of physical activity level groups for outdoor volleyball

Figure 2. Schematic diagram of the study population

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3.2. ANALYTICAL MODEL OF THE EFFECT OF OUTDOOR VOLLEYBALL EXERCISE ON CARDIORESPIRATORY FITNESS

In this study, a mixed linear model with fixed and random effects was used to investigate the relationship between volleyball exercise activity level and cardiorespiratory fitness in a heavy haze environment. The analysis involved continuous variables such as age, body mass index, systolic blood pressure, diastolic blood pressure, and volleyball exercise activity level, as well as categorical variables such as gender, body mass index classification, particulate matter category, and outdoor volleyball exercise activity level. The construction process of the mixed linear model is as follows.

A simple linear model was established with systolic or diastolic blood pressure as the independent variable and other variables as the dependent variables, as follows.

$$Y = XB + U \quad (2)$$

Where Y is the dependent variable; X is the independent variable; B is the estimated parameter matrix; and U is the error matrix.

Record the statistically significant variables in the simple linear model.

Gradually add a random variable to ensure the significant variables in step 2. At the same time, the performance of the model is evaluated using the bare pool informativeness criterion and the Bayesian information criterion auxiliary indicator. Step 3 is repeated until either the deficit pool informativeness criterion or the Bayesian information criterion for the potential candidate model is found [38-39].

Based on the potential model in step 3, two or more random variables are gradually added to determine the significant variables in step 2. At the same time, the bare pool informativeness criterion and the Bayesian information criterion are applied to the performance evaluation of the model. This step is repeated until a potential candidate model is found for either the deficit pool informativeness criterion or the Bayesian information criterion.

Adjust the random intercept in the random structure until the best model with the minimum value of the Bayesian information criterion is found.

Compare the models from steps 2, 3, 4, and 5 with the analysis of variance methods to obtain a significantly improved model. Based on the model structure, the effects of random variables are represented graphically.

Mixed linear model analysis was performed with systolic and diastolic blood pressure as dependent variables and age, height, weight, body mass index, metabolic equivalent, PM2.5-0day, PM2.5-7day, PM2.5-15day, PM2.5-30day, and PM2.5-60day as independent variables, respectively.

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The Pearson model was used to filter and compare multiple variables, and the dependent variable with the highest correlation with the cardiopulmonary dependent variable was selected for modeling to derive the index with the greatest impact on cardiopulmonary, resulting in the optimal model equation in systolic blood pressure.

$$hyper - value \sim 1 + age + height + (1 + weight / met - class) + (1/BMI - class) \quad (3)$$

The same modeling approach was used to select the higher correlation variables for diastolic pressure modeling, and in the diastolic pressure model, the optimal model was:

$$hyper - value \sim 1 + pmvalue * weight + age + (0 + age/ met - class) + (1/ gender) + (weight / BMI - class) \quad (4)$$

It was found that volleyball motor activity level classification and body mass index classification were important random terms in both systolic and diastolic models, and gender was an important random term in the diastolic model. Therefore, based on the results of the systolic and diastolic blood pressure models, gender, volleyball sports activity level, and their interactions were emphasized.

4. RESULTS AND ANALYSIS

Using the systolic optimal model and diastolic optimal model, the effects of volleyball exercise on the cardiopulmonary function of the target subjects under a heavy haze environment in the recent year were investigated. The model analysis results of the daily average of each cardiorespiratory function index shown in Figure 3 were obtained.

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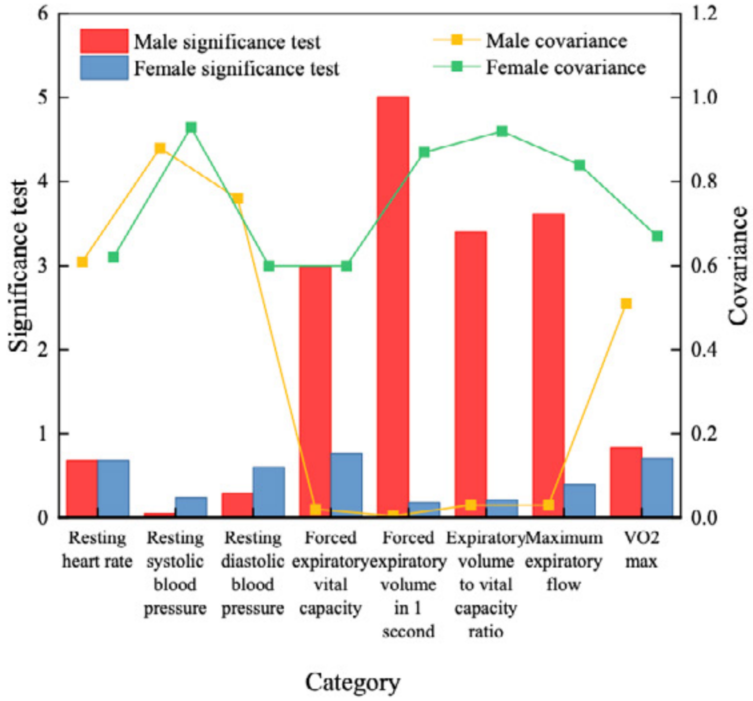
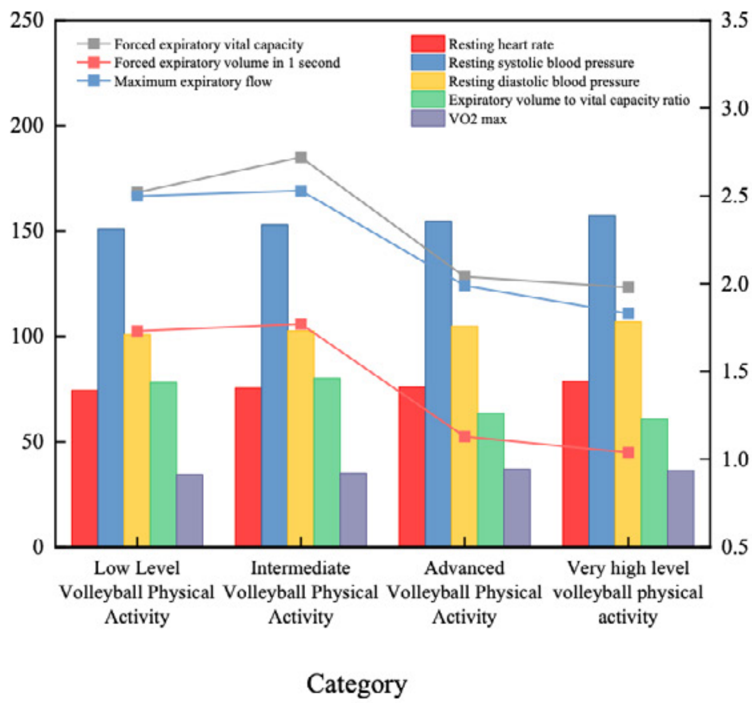


(a) Association test between volleyball and cardiopulmonary function by gender



(b) Cardiorespiratory fitness indices of men in different physical activity groups of volleyball

Figure 3. Effect of volleyball exercise on human cardiopulmonary function under heavy haze environment

The results of the association test analysis between volleyball exercise and cardiopulmonary function by gender (see Figure 3(a)). The significance test for quiet heart rate was 0.68 with a covariance of 0.61. The significance test for quiet systolic blood pressure was 0.05 with a covariance of 0.88. The significance test for quiet diastolic blood pressure was 0.29 with a covariance of 0.76. The significance test for expiratory volume per second was 2.99 with a covariance of 0.02. The significance test for expiratory volume per second was 5.01 with a covariance of 0.004. The significance test value of expiratory volume to spirometry ratio was 3.4 with a covariance of 0.03. The significance test value of maximum expiratory flow was 3.62 with a covariance of 0.03. The significance test value of maximum oxygen uptake was 0.83 with a covariance of 0.51.

Among them, the significance test values of quiet heart rate, quiet systolic blood pressure, quiet diastolic blood pressure indexes, and maximum oxygen uptake related to cardiac function were all less than 1, and the covariance values were all greater than 0.5. The above data indicate that significant interaction effects were found on four indexes of pulmonary ventilation function in men: expiratory lung volume with force, expiratory volume with force in 1 second, expiratory volume to lung volume ratio, and maximum expiratory flow. However, no interaction effect of volleyball exercise in a heavy haze environment was found on cardiac function and maximal oxygen uptake in males. For all cardiopulmonary function indicators in women, the significance test value for quiet heart rate was 0.68. the covariance was 0.62. the significance test value for quiet systolic blood pressure was 0.24 and the covariance was 0.93. The significance test for quiet diastolic blood pressure was 0.69 with a covariance of 0.6. The significance test for expiratory volume per second was 0.76 with a covariance of 0.6. The significance test for expiratory volume per second was 0.18 with a covariance of 0.87. The significance test for expiratory volume to spirometry was 0.21 with a covariance of 0.92. The significance test for maximum expiratory flow was 0.39 with a covariance of 0.84. The significance test for maximum oxygen uptake was 0.7 and the covariance was 0.67. The significance tests for all cardiopulmonary function indicators were less than 1 and the covariance was greater than 0.5, indicating that there was no significant interaction effect of volleyball on cardiac function, pulmonary ventilation, and maximum oxygen uptake in women in heavy haze. This revealed that volleyball physical activity in a heavy haze environment produces different health effects (predominantly on lung function) in study subjects of different genders, but the mechanisms involved are currently unclear. The main reason for this is that it is not clear whether the differences between genders are due to differences in physiological mechanisms or due to different social attributes. This may also contribute to the fact that no significant differences were found in pulmonary ventilation function in girls in this study.

Figure 3(b) presents an analysis of cardiopulmonary function indicators (except quiet heart rate, quiet systolic blood pressure, quiet diastolic blood pressure indicators, and maximum oxygen uptake) in men within different volleyball physical activity groups. The results showed that in the high-grade and very high-grade volleyball physical activity groups, the mean values of 1-second expiratory volume, expiratory volume to spirometry ratio, and maximum expiratory flow were lower than those in the low-grade and medium-grade volleyball physical activity groups. For

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significant cardiorespiratory function in the low-grade volleyball physical activity versus mid-grade volleyball physical activity groups, the longer the volleyball exercise time, the greater the index values (i.e., 2.72 L > 2.52 L, 1.77 L > 1.73 L, 80.1% > 78.91%, 2.53 L > 2.5 L). For cardiorespiratory fitness that was significant in the high-grade volleyball physical activity and very high-grade volleyball physical activity groups, the longer the duration of volleyball exercise, the smaller the index values (i.e., 1.98 L < 2.04 L, 1.04 L < 1.13 L, 60.78% < 63.63%, 1.83 L < 1.99 L). The reason for the results of this study may be that the benefits of volleyball exercise on human cardiorespiratory function outweigh the negative effects of heavy haze when the physical activity has not yet reached the level of high-grade volleyball physical activity. At this point, the higher the level of volleyball physical activity, the better the state of cardiorespiratory function. Volleyball brought greater physical benefits to the target group by lowering blood pressure and improving pulmonary ventilation and maximum oxygen uptake in the study subjects. It also completely suppressed the negative physical effects of fine and respirable particulate matter in a heavy haze environment. causing the target subject's expiratory lung volume with force, expiratory volume with force in 1 second, expiratory volume to lung volume ratio, and maximum expiratory flow rate to increase from 2.52 L, 1.73 L, 78.91%, and 2.5 L to 2.72 L, 1.77 L, 80.1%, and 2.53 L, respectively. but when physical activity reaches high levels of volleyball physical activity and above, not only is the respiratory rate typically faster, but also the probability is that breathing will be done through the mouth. This bypasses the filtration effect of the nasal cavity, leading to more pollutant inhalation, irritating the respiratory system, triggering inflammation, or obstructing the airway. At this point, the positive effects of volleyball on human cardiorespiratory function, such as lowering blood pressure, are far less than the risk of greater exposure of the human body to large amounts of particulate matter that accumulate at low altitudes and do not diffuse easily during breathing at faster respiratory rates. This results in the body's cardiorespiratory function being far more susceptible to the pollution conditions of a heavy haze environment than at low levels of volleyball physical activity versus medium levels of volleyball physical activity. This resulted in a significant decrease in the target subjects' forceful expiratory lung capacity, 1-second forceful expiratory volume, expiratory volume to lung capacity ratio, and maximum expiratory flow rate due to obstructive ventilation dysfunction, obstructive emphysema, respiratory ventilation dysfunction, restrictive ventilation dysfunction, or mixed ventilation dysfunction caused by heavy haze, from 2.04 L, 1.13 L, 63.63%, and 1.99 L, respectively decreased to 1.98 L, 1.04 L, 60.78%, and 1.83 L. In conclusion, excessive physical activity of volleyball in a heavy haze environment can aggravate the inhalation of respirable particulate matter, resulting in the negative effects of a heavy haze environment for the body, overriding the benefits of volleyball for the body.

5. DISCUSSION

For volleyball to achieve its essential role, the hazy environment needs to be effectively improved, but the improvement process takes time to achieve. During this

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time, volleyball players need to take protective measures to avoid damage to their cardiopulmonary function. The following measures are proposed for the improvement of the haze environment and the protection of volleyball:

1. Volleyball courts are mostly located in the square and other open areas close to the road so sportsmen are directly affected by the hazards of automobile exhaust. There are hundreds of undesirable substances in automobile exhaust. In addition, car exhaust also contains many types of polycyclic aromatic trails, which contain carcinogenic substances. Therefore, it is important to avoid inhaling automobile exhaust fumes as much as possible. The government should take appropriate means to reduce exhaust emissions by formulating reasonable policies to limit the number of vehicles.

2. Wear a professional mask and try to exercise indoors. In hazy weather, masks must be worn outside, and professional medical masks should be chosen. It is recommended to use anti-viral masks, in which the filter layer can filter out some of the bacteria in the haze. More indoor places such as gymnasiums or sports activity centers for volleyball can effectively reduce the amount of haze inhaled.

3. Minimize the consumption of stimulating foods. Since the air pressure is relatively low in hazy weather, groups with poor cardiorespiratory fitness should try not to engage in volleyball or other relatively strenuous exercise. You can eat more items such as pears and lilies. Garlic and shallots both have antiseptic effects, and more of the above-mentioned foods can be eaten in hazy weather to increase immunity.

6. CONCLUSION

Current air pollution levels are becoming increasingly severe, and heavy haze weather environments are strongly associated with increased morbidity and mortality from cardiopulmonary disease. People are increasingly concerned about physical health issues, and more and more people are involved in outdoor physical exercise and sports. Therefore, in this paper, the study population was selected based on the spatial and temporal distribution characteristics of heavy haze in the study area. Based on the quartiles of the daily total metabolic equivalent values of volunteers, the physical activity level groupings for outdoor volleyball were classified. A mixed linear model in which the independent variable was systolic or diastolic blood pressure was used to explore the relationship between the effects of outdoor volleyball exercise on cardiorespiratory fitness in a heavy haze environment, and three concluding points were obtained.

1. Volleyball physical activity in a heavy haze environment produces different health effects on study subjects of different genders. The significance test values for male forceful expiratory spirometry, 1-second forceful expiratory volume, expiratory volume to spirometry ratio, and maximum expiratory flow

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were all greater than 1, and the covariance values were all less than 0.5. Therefore, there was an interaction effect of volleyball exercise on pulmonary ventilation function in males. The significance test values of all cardiopulmonary function indexes in women were less than 1, and the covariance values were all greater than 0.5, so the interaction effect of volleyball exercise on women was not significant.

2. When physical activity has not yet reached the level of high-grade volleyball physical activity, the benefits of volleyball to human cardiorespiratory function outweigh the negative effects of heavy haze. Exercise improved pulmonary ventilation function and maximum oxygen uptake by lowering the blood pressure of the study subjects, resulting in an increase in their pulmonary ventilation function index from 2.52 L, 1.73 L, 78.91%, and 2.5 L to 2.72 L, 1.77 L, 80.1%, and 2.53L, respectively.

3. When physical activity reaches the level of advanced and very high volleyball physical activity, the filtering effect of the nasal cavity is bypassed due to the accelerated breathing rate. This resulted in a decrease in the lung ventilation function index of the target subjects from 2.04 L, 1.13 L, 63.63%, and 1.99 L to 1.98 L, 1.04 L, 60.78%, and 1.83 L, respectively.

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