Relationship between Particulate Matter Exposure and Inhaled Amount for Different Exercise Patterns of Healthy Adults

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Abstract. Air pollution has increasingly become a threat to people's daily life. Exposure to air pollution will have a negative impact on people's health. However, little research has been done on the impact of air pollution on people's different ways of exercise. The purpose of this study is to explore and determine the relationship between particulate matter that has an aerodynamic diameter of 2.5 microns or smaller (PM_{2.5}) exposure and different exercise patterns of healthy adults. Thirty volunteers were recruited and validated by the equivalent model of PM_{2.5} approximate inhalation volume-time. The predictive model of PM_{2.5} particulate matter exposure (y) and time (x) was derived as follows: y = 1.4663x - 593.41. It is concluded that when people are exposed to air, the shorter the exercise time, the less PM_{2.5} will be inhaled. Therefore, when people exercise outdoors, the use of fast running will be the best way of reference, and the amount of PM_{2.5} inhaled is the least.

1. Introduction

Environmental pollution has increasingly become the focus of attention [1-4]. Among them, air pollution has become the greatest threat to health. In 2018, the World Health Organization counted that about 3 million people die each year in areas where air pollution levels exceed normal levels. According to statistics, 90% of the population currently lives in this area [5]. Therefore, people are paying more and more attention to the impact of air pollution on human health, which means that the conceptual framework of the relationship between environmental-health-economic policies is particularly prominent in the global debate on air pollution. Nitride, sulfide, PM_{2.5}, PM_{10} and other fine particles in the air have direct or indirect negative effects on human health. Samuel Asumadu Sarkodie et al. conducted a survey in Europe, Australia, the United States and Canada. The environmental Kuznets curve hypothesis confirmed that environmental air pollution had a significant impact on reducing life expectancy and increasing mortality [6]. In China, Yaohua Tian et al. investigated the relationship between air fine particulate matter pollution and hospital hospitalization rates in more
than 200 cities in China. The results showed that short-term exposure to PM$_{2.5}$ was positively correlated with adult hospitalization rate [7]. However, the relationship between short-term exposure to environmental fine particulates and risk of disease in developing countries like this is not fully understood and little research has been done.

As we all know, PM$_{2.5}$ is one of the main sources of air pollution. It is not only the carrier of many pollutants, but also contains many harmful substances. These include carbonaceous components and water-soluble compounds. Secondary organic aerosols (SOA) play an important role in climate. It can be produced directly from primary fossil fuel combustion, biomass combustion and cooking. It changes the visibility of the atmosphere by affecting solar radiation and forms a “Smog” weather [8]. It can also cause chronic respiratory diseases and even cancer, which has a great impact on people’s health. As the political center of Shandong Province, Jinan has a long history. But the air pollution in Jinan is very serious every year. Therefore, scholars at home and abroad are paying more and more attention to the sources, components and health effects of PM$_{2.5}$. However, these studies seldom involve the approximate values of PM$_{2.5}$ exposure to atmospheric fine particulates, and directly derive people’s short-term PM$_{2.5}$ inhalation. Accordingly, the purpose of this study is to explore the relationship between PM$_{2.5}$ exposure and exercise mode in short-term outdoor exposure to air, and to provide an approximate calculation model, so as to provide an optimal reference exercise mode for outdoor sports or tourism.

2. Experiments

2.1. Subjects

When people exercise outdoors, they usually do it in three ways: slow walking, jogging and running. Therefore, the experimental design determines these three common modes of motion. Thirty volunteers, aged about 20 years, were recruited in this study, including 15 males and 15 females. On February 23, 24 and 26, respectively, the weather conditions were basically the same, and the pollution situation was roughly the same. The concentration of PM$_{2.5}$ was 83 ug/m$^3$. The experiment was carried out by slow walking, jogging and running. The area near Qianfo Mountain in Jinan City was used as the experimental site. At the same time, the travel distance of the experiment is set to 800 meters, and the experiment distance can be set to other values according to the need. Before and after the exercise, the volunteers measured and recorded the PEF value. After the exercise, the exercise time of each experiment was recorded.

2.2. Technical route:
The general technical route of this experiment is shown in Figure 1 below.

3. Analysis

3.1. Experimental prediction method

Data acquisition: Volunteers’ exercise time was recorded as t. The PEF of the volunteers was recorded as a before the exercise test. The PEF of the volunteers was recorded as B after the exercise test. The average breathing volume of the volunteers during the whole exercise period was replaced by the average breathing volume of each breathing exercise. The concentration of PM$_{2.5}$ in the atmosphere on that day was recorded as C from the concentration of PM$_{2.5}$ released by Jinan Meteorological Station. Finally, the approximate amount m of PM$_{2.5}$ inhaled in the volunteer laboratory was obtained.

$$m = \left( \frac{a+b}{2} \right) \times r \times t \times c$$  \hspace{1cm} (1)

According to the data provided by Jinan Meteorological Monitoring Center, PM$_{2.5}$ particulate matter concentration in February in Jinan City is 83ug/m$^3$. By substituting the data into the formula
The scatter plots of PM$_{2.5}$ approximate inhalation volume and exercise duration of volunteers in slow walking mode are sorted out, as shown in Figure 2. The time length of jogging - PM$_{2.5}$ approximate inhalation scatter plot is shown in Figure 3. The time length of fast running - PM$_{2.5}$ approximate inhalation scatter plot is shown in Figure 4.

\[ m = \left( \frac{t+b}{2} \right) \times r \times t \times c \]

**Figure 1. Flow Chart**

**Figure 2. Time-PM$_{2.5}$ approximate inhalation scatter plot in slow walking mode**
It is easy to know from the scatter plot obtained from the experimental prediction method that the relationship between exercise time and PM$_{2.5}$ approximate inhalation volume is positively correlated, so the shorter the exercise time is, the less the approximate inhalation volume of PM$_{2.5}$ will be. Next, we will use the software MATLAB to fit the data into corresponding functions to verify.

3.2. PM$_{2.5}$ Approximate Inhalation Volume-Time Equivalent Model Method

According to the experimental data and calculation results obtained under three motion modes, three functional conclusions can be fitted by MATLAB programming. The fitting function of time-PM$_{2.5}$ approximate inhalation volume (y) and time (x) under slow walking mode is $y = 0.6077x - 134.93$. The fitting function of time-PM$_{2.5}$ approximate inhalation (y) and time (x) under jogging mode is $y = 1.4663x - 593.41$. The fitting function of time-PM$_{2.5}$ approximate inhalation (y) and time (x) under fast running mode is $y = 0.0256x + 4.0601$. The three fitting functions are compared with the experimental data of the new tester. The average PEF of the new participants in jogging, jogging and fast running was 265, 460 and 289, respectively. The duration of exercise was 667, 131 and 255, respectively. The approximate inhalation volume of PM$_{2.5}$ with the substitution formula $m=\left(\frac{a+b}{2}\right)\times \text{r}\times \text{t}\times \text{c}$ was 244.51ug, 83.36ug and 101.94ug, respectively. Compared with the approximate values obtained by the fitting function, the approximate inhaled volume of PM$_{2.5}$ determined by the fitting function under the slow walking mode is 81.088ug. The results of the two methods are very close, with an error of 2.8% and less than 5%. It shows that the fitting degree is good. So the linear function model of this experiment can be obtained as follows: $y = 1.4663x - 593.41$ to approximately calculate the inhalation amount of PM$_{2.5}$ exposed to air in people's daily life.
It can be concluded that the approximate inhalation volume of PM$_{2.5}$ has a positive linear relationship with exercise time. Therefore, in this study, the best three kinds of sports were fast running, and the least amount of PM$_{2.5}$ inhaled.

4. Discussion
It is impossible to directly measure PM$_{2.5}$ inhalation volume from short-term air exposure in order to associate exercise patterns with PM$_{2.5}$ inhalation [9-11]. We have done a preliminary experiment in which the experimenter wears a 3M mask to isolate PM$_{2.5}$ from the inhaled gas during outdoor exercise. PM$_{2.5}$ is measured by eluting the mask. However, the result is that PM$_{2.5}$ will not come out no matter how the elution method is changed. Finally, after consulting the literature and consulting experts, we rejected the original direct measurement method. Because, the first and third M masks can not isolate PM$_{2.5}$; second, in outdoor sports, when the human body wears the masks, the amount of inhaled gas will flow through the gap at both ends of the masks, resulting in a loss. Therefore, our current experimental idea is to transform this measurement method to measure the net air intake of human body during outdoor exercise, and then multiply the PM$_{2.5}$ gas concentration of Jinan City on that day, so as to approximately calculate the PM$_{2.5}$ inhalation of human body during this period. By comparing the data with different movement modes, the relationship between PM$_{2.5}$ particulate matter exposure and different movement modes was explored.

We predict that the approximate inhalation volume of PM$_{2.5}$ will be positively correlated with the duration of exercise. The shorter the duration of exercise, that is, the shorter the duration of exposure to air, the less the approximate inhalation volume of PM$_{2.5}$ will be. Therefore, two methods were used to validate this study: the experimental prediction method and the equivalent model of PM$_{2.5}$ approximate inhalation volume-time. From the above experimental results, we can see that both methods verify the correctness of our method. Therefore, we suggest that when people travel or exercise outdoors, the shorter time they are exposed to the air, the healthier they will be. Proper exposure should be a necessary consideration when people travel outdoors.

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