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Effects regularly exercising in two different $PM_{2.5}$ concentration

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ABSTRACT

Performing exercise or physical activities for a long duration under the exposure of air pollution becomes an unhealthy combination and will increase the risks of the individual inhaling more pollutant. Studies that examine an individual performing physical activities regularly in two public sport centers with different levels of air pollution have not been extensively documented, therefore the purpose of this study is to evaluate effects of regular exercise on aerobic capacity, force vital capacity (FVC), and hematological profile among individuals in an environment with similar climatic characteristics but different concentrations of air pollution. This trial composed 15 males (age range from 16 to 18) from Bandung City, Indonesia. Two public sport centers with similar climatic conditions (temperature, and humidity), but different concentrations of air pollutants are selected. Participants performed exercises three times a week for three consecutive weeks at each research site, with a two-week break. Participants' aerobic capacity, respiratory capacity, and blood sample are measured before and after they exercised at each site. The measured parameters in both sites are compared and analyzed. Aerobic capacity, FVC, and RBC after participants exrcised in the area with lower air pollution show higher value than exercised in the area with higher air pollution. Manwhile WBC is shown to be high after participants exercised in the area with higher air pollution. This happened because air pollution has effect to human physiological characteristics. This research shows that exercising at sport center with high air pollution had negative effect on hematology profile and could affect the development of aerobic and respiratory capacities. The limitations in this study are the unknown intensity when doing regular physical exercise so that in future studies it is recommended to determine whether the intensity will affect the variables in the research subject.

Keywords: Air pollution; health; physical activities; public sport center

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Authors' Contribution: a – Study Design; b – Data Collection; c – Statistical Analysis; d – Manuscript Preparation; e – Funds Collection

INTRODUCTION

The level of air pollution will continue to increase along with the booming of population and economic activities (Giorgini et al., 2016; Ottosen & Kumar, 2020; Ramos et al., 2014; Wagner & Clark, 2018). There are two common types of pollutant resulted from air pollution, i.e. particulates ($PM_{2.5}$, PM10, TSP) and gas pollutant (CO, SO_2, NO_2, O_3) (Lü et al., 2015; Qonitan et al., 2015; Xing et al., 2016). Some studies have reported the short-term and long-term effects of air pollution on the increase of mortality and morbidity risks

(Cohen et al., 2017; Nazar & Niedoszytko, 2022). $PM_{2.5}$ is one type of particulate less than 2.5 micron and can enter not only the respiratory system but also straight to the lungs (An et al., 2018; Xing et al., 2016). Previous studies have shown that long term exposure to $PM_{2.5}$ can cause the decrease in lungs functions (Bahri et al., 2021; Cutrufello et al., 2012; Kim et al., 2018; Xing et al., 2016).

Air pollution affects all human activities, including physical activities and WHO has recorded as well as estimated that there were about 7 million deaths in 2012 related to living in areas polluted by air pollution, so that air pollution is a global problem that affects many countries around the world (Azuma et al., 2018). Air pollution affects all human activities, including physical activities. Air pollution affects individuals who perform physical activities or exercises at public sport centers that are located near main roads full of motor vehicles. Previous studies have indicated that public sport centers near main roads have high concentration of air pollutant (Muliane & Lestari, 2014; Qonitan et al., 2015) and indirectly make people have to exercise at a place where they will be exposed to air pollution. The benefits of regular exercise have been shown to significantly increase physical and mental health benefits as well as reduce the risk of morbidity and mortality (An et al., 2017; Aydin et al., 2014; Sinharay et al., 2018). Despite there are significant health benefits to our bodies due to regular exercise, performing exercise or physical activities for a long duration under the exposure of air pollution becomes an unhealthy combination and will increase the risks of the individual inhaling more pollutant. Several previous studies have reported that individuals who performed exercising in conditions of high air pollution tend to experience changes in their hematological profiles (Das & Chatterjee, 2015; Kargarfard et al., 2015).

Public sport centers in big cities tend to be located near main roads, which present another health risk because those who exercise at the site will do so under high level of air pollution (Li et al., 2016; Nazar & Niedoszytko, 2022). Several studies have indicated that respiratory problems and other bodily function defects during physical activities are affected by short-term exposure to air pollution (Bahri et al., 2021; Cutrufello et al., 2012; Das & Chatterjee, 2015; Kargarfard et al., 2015). In recent years there has been some debate about whether to do, limit, or even not do exercise at all in places with high air pollution so that this becomes an interesting challenge for researchers to conduct research and study doing exercise regularly in public sports places that tend to be exposed to air pollution. Studies that examine an individual performing physical activities regularly in two public sport centers with different levels of air pollution have not been extensively documented. Some previous studies only carried out descriptive research, did not experimentally (Das & Chatterjee, 2015; Kargarfard et al., 2015). Hence, this study is to compare effects of regularly exercise on force vital capacity (FVC), aerobic capacity, and hematological profile including Red Blood Cells (RBC) and White Blood Cells (WBC) among young individuals in an environment with similar climatic characteristics but different concentrations of air pollution.

METHOD

Participant

Fifteen students (average age of 18.5 ± 0.5 years old) who do not suffer from cardiovascular disease, asthma, and do not smoke are recruited to participate in this research. All participants are given an explanation, in speech and in writing, regarding the goals, procedures, and risks of the research. All participants are selected by purposive sampling methods. The participants are directed to fill in informed consent form should they decide to participate in the research. The protocol of this research had been approved by the research ethics comitee of the Padjajaran University.

Study Design

The study was conducted using a quasi-experimental design with one group pretest and posttest measurements without control group because olny to observe one group with two differents sport centre. Before conducting the exercise program, anthropometric data, FVC, and blood sample were measured. Participants underwent a treatment of exercising in public sport center in the evening with measurable $PM_{2.5}$ level three times a week for three consecutive weeks. The exercise program consisted of 5 minutes of warming up, 30 minutes sub-maximum exercises, and 5 minutes cooling down. The participants were instructed not to change their diet and not to consume dangerous drugs during the course of the research. Anthropometric data, FVC, and blood sample were measured again after three weeks of treatment. After a fourteen-day interval, similar treatment was repeated in the other research site (see figure 1).

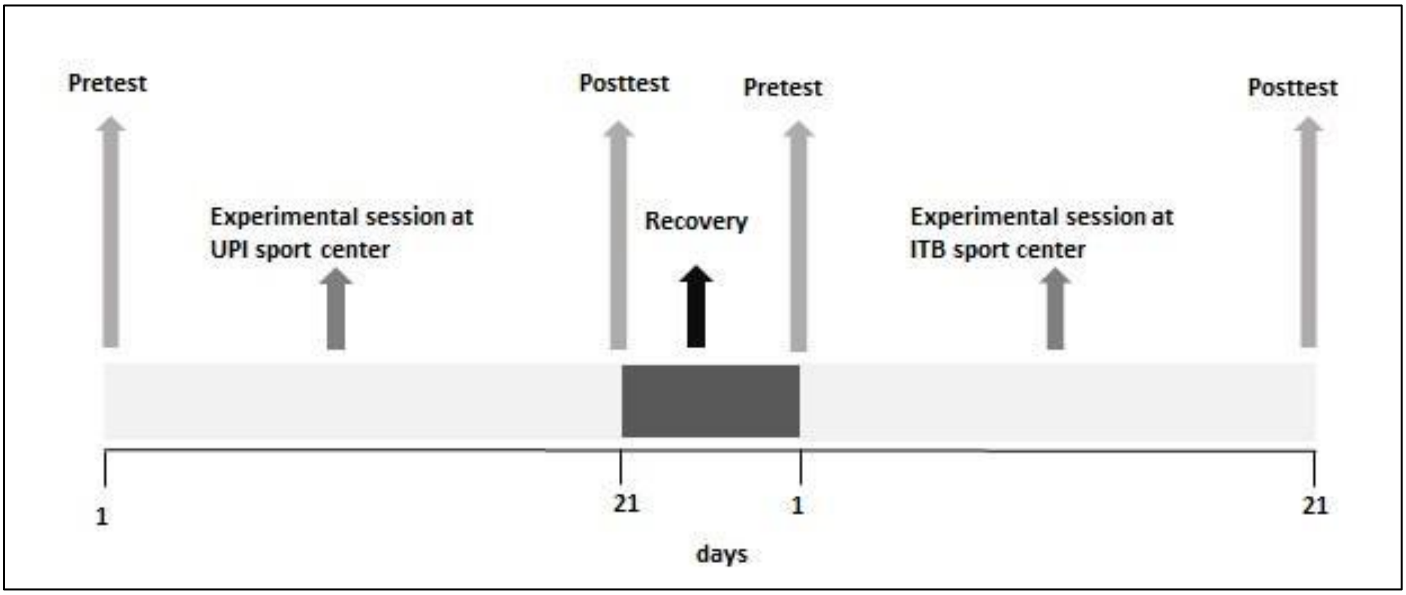

Figure 1. Study Design

Research Site Selection

Two public sport centers, namely ITB sport center and UPI sport center, in Bandung City, Indonesia, were selected to be the sites for this research. ITB sport center is located between Siliwangi Street and Tamansari Street, while UPI sport center is located in the campus of UPI Bandung (see figures 2 and 3).

Figure 1. UPI Sport Center

Figure 3. ITB Sport Center

Procedures

Weather Stations and Laser Egg instruments were placed 10 meters above the ground. The sensors in these instruments recorded the temperature, humidity, and $PM_{2.5}$ level of the surrounding area. These data could be examined live via Breathing Space application, which was connected to a smartphone. Body mass, in kilograms, was measured on OMRON Karada Scan HBF-375. Height, in meters, was determined with Stadiometer. Body mass index (weight/height^2) was calculated to chatacterize sample. Furthermore, all participants were asked to sit down and inhaled as much air as they could and exhale as much air from their lungs as possible into Spirometer SP10 instrument. FVC level was automatically recorded when a participants did so. Next all participants were asked to fast and not to perform heavy activities on the evening prior to blood sample taking. 15 cm^3 of venous blood was taken from antecubital vena. The blood was frozen at room temperature before it was centrifuged. The centrifuged blood was then kept in a freezer at -85 °C for analysis. Hematology profiles were measured at Brawijaya Clinic of Bandung City.

Statistical Analysis

The findings were displayed in means and standard deviation data. Before the significance level was analyzed, normality and homogeneity tests were conducted using Shapiro Wilk Test. The significance level per group was measured using dependent t-test. Two-way ANOVA was utilized to compare hematology profiles and lungs vital capacity before and after the treatment. Considering that the participants had been exposed to various level of $PM_{2.5}$ concentration, paired t-test was employed to compare pre-treatment and post-treatment groups in low $PM_{2.5}$ and high $PM_{2.5}$ conditions, as well as the changes in variables to determine correlation between variables, if any. All statistical analysis was done using SPSS (version 22, IBM Corp, Somers, NY). The statistical significance was accepted at alpha $p < 0.05$.

Ethical Approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the research ethics comitee of the comitee of the Poltekes Bandung. Informed consent has been obtained from all individuals included in this study.

RESULTS AND DISCUSSION

The height and weight of the participants (mean ± SD) are 157.82 ± 4.56 cm and 43.08 ± 3.85 kg, respectively. Table 1 and 2 respectivly showed the average $PM_{2.5}$ concentration at 19.00 local time, when the treatment group was performing physical activities.

Table 1. Characteristics of UPI Sport Center

Date	$PM_{2.5}$	Temperature (° C)	Humidity (%)
1/1/2022	89	24	78
4/1/2022	93	22	80
6/1/2022	87	23	81
9/1/2022	79	24	81
11/1/2022	81	22	79
13/1/2022	84	21	80
16/1/2022	82	21	77
18/1/2022	76	23	80
20/1/2022	80	22	76
Avarage	83.44	22.44	79.11

Table 2. Characteristics of ITB Sport Center

Date	$PM_{2.5}$	Temperature (° C)	Humidity (%)
5/2/2022	103	25	76
7/2/2022	98	24	78
9/2/2022	108	22	77
22/2/2022	96	26	81
14/2/2022	95	23	80
16/2/2022	105	23	74
19/2/2022	108	24	76
21/2/2022	112	25	81
23/2/2022	96	24	76
Avarage	102.33	24	77.67

The data are a result of real time measurement using Laser Egg Origins that were installed next to the track at both public sport centers. Laser Egg Origins indicated that the average $PM_{2.5}$ concentration at ITB sport was higher than that at UPI sport center.

Table 3. Characteristics of Changes in Variables After Exercise in Public Sports

Variable	UPI Sport Center		ITB Sport Center	
	Before	After	Before	After
VO_2 max (mL/kg/min)	52.02±2.64	52.71±2.98	51.92.±2.52	52.12±2.76
FVC (L)	3.40±0.25	3.54±0.30*	3.42.±0.32	3.44±0.38
White blood cell (x 10^3 /µl)	8.28±1.68	9.20±1.75*	8.42±1.63	9.81±1.58*
Red blood Cell (million/mm^3)	4.91 ±0.26	4.79 ±0.28	4.89±0.31	4.82±0.32

The values are presented as mean ± standar deviation
Independent t-test, *values significantly among pre-test and post-test ($p < 0.05$)

Table 3 shows the average VO_2 max, FVC, and hematology profiles data before and after the participants performing physical activities three times a week for three consecutive weeks at the two public sport centers. The data in table 3 indicates that VO_2 max and FVC levels after exercising at ITB sport center, which had higher concentration of $PM_{2.5}$, were lower than that at UPI sport center. Meanwhile, hematology parameter of RBC experienced a higher level of decrease after exercising at ITB sport center than RBC after exercising at UPI sport center. Furthermore, WBC significantly increased after physical activities at ITB sport center compared to WBC after exercising at UPI sport center.

The measurement result of Laser Egg Origins shows that the average $PM_{2.5}$ concentration during the time of the treatment (i.e. 19.00 local time), in which the participants performed physical activities, was 78.86 µg/m3 at UPI sport center and 104.72 µg/m^3 at ITB sport center. This data indicates that both sites have relatively high average $PM_{2.5}$ concentration. However, it did not exceed the ambient air pollution recommended by WHO (Sinharay et al., 2018). WHO stated that the ambient air pollution of $PM_{2.5}$ was 25 µg/m^3 per day (24 hours) and 10 µg/m^3 per year, and per hour recomendation was not given. High concentration of $PM_{2.5}$ at the two sites during the period of the treatment was due to the increase in vehicle activities on the streets near the sites. The $PM_{2.5}$ concentration at ITB sport center was higher because the site was closer to the road, unlike UPI sport center which was located further away from the main roads. The result of $PM_{2.5}$ measurement instrument installed at both sites was relatively similar to that found in previous studies, that $PM_{2.5}$ concentration level at a sport center near a main road is relatively high and that the highest concentration of $PM_{2.5}$ at such as site is in the evening (Cutrufello et al., 2012; Qonitan et al., 2015; Vecchi et al., 2007; Xing et al., 2016).

This research shows an increase of FVC on the participants after exercising three times a week for three consecutive weeks at both UPI and ITB sport centers. The increase of FVC on the participants is higher after they performed physical activities at UPI sport center compared to the increase of FVC on participants after performing exercises at ITB sport center. This finding indicates that performing physical activities such as exercising under exposure of high concentration of $PM_{2.5}$ indirectly hinders FVC increase. This may be due to the nature of $PM_{2.5}$ that can enter the lungs and settle in alveoli. $PM_{2.5}$ that settles in alveoli may cause fibrosis of the lungs and if 10% of the alveoli hardens, it will reduce its elasticity in accommodating air (Bahri et al., 2021; Wilson & Eatough, 2004; Xing et al., 2016).

This finding is different from the findings of previous studies, in which it was stated that exposure to $PM_{2.5}$ for certain period of time tended to cause a decrease in FVC. This difference is most likely because the participants in previous studies only performed normal daily activities, without exerting any heavy physical activities, even though the $PM_{2.5}$ concentration in the air was high (Bahri et al., 2021; Cutrufello et al., 2012; Kim et al., 2018; Lin et al., 2014). The findings in this research indicate that performing physical activities at public sport center with high level of $PM_{2.5}$ exposure increases FVC rather than decreases it. It is because regularly performing physical activities will increase immune system and strengthen respiratory muscles, as well as increasing lungs capacity (Bahri et al., 2021; Caetano et al., 2015; Mathisen & Pettersen, 2018; Wagner & Clark, 2018).

This research shows that performing physical activities in sites with different levels of $PM_{2.5}$ concentration correlates with the changes in participant hematology profiles. In this research, the participants experienced a significant decrease in RBC after performing physical activities at ITB sport center. Meanwhile, after exercising at UPI sport center, the participants also experienced a decrease in RBC, even though it was not significant. The lower RBC of the participants after exercising at ITB sport center, which had higher concentration of $PM_{2.5}$ than UPI sport center, was most likely due to the minute increase in blood volume when they were exposed to higher concentration of air pollutant, as documented in previous experimental studies (Bahri et al., 2020; Das & Chatterjee, 2015; Kargarfard et al., 2015; Bahri et al., 2019).

Furthermore, this research also finds an increase in participants WBC after performing physical activities in both sites. However, higher concentration of WBC was found after the participants performing physical activities at ITB sport center. This finding is similar to that of previous studies, in which it is reported that individuals who perform physical activities in lower level of air pollution will have lower WBC than individuals who perform similar exercises in higher level of air pollution (Apriantono et al., 2020; Das & Chatterjee, 2015; Kargarfard et al., 2015; Liao et al., 2005). The increase in WBC after the participants performed physical activities in an environment with high level of $PM_{2.5}$ exposure might be caused by the effect of $PM_{2.5}$, which can damage tissues in human body and causes the body to produce more antibody as a response to the high level of $PM_{2.5}$ exposure.

The findings of this research show an increase in aerobic capacity after the participants performing physical activities at both sites. This indicates that exercising regularly can increase an individual's aerobic capacity. In other words, an individual who fails to perform physical activities for a certain period of time will gradually experience a reduced aerobic capacity. However, higher increase of aerobic capacity was found after the participants exercised in UPI sport center compared to when they exercised in ITB sport center. The results of this study demonstrated a lower value for aerobic capacity after a physical activity in a highly polluted area, which illustrates that endurance performance is adversely affected by polluted air. This is reported to be associated with an impaired oxygen distribution function and pulmonary dysfunction while performing exercise in polluted air (Bahri et al., 2021; Das & Chatterjee, 2015; Kargarfard et al., 2015).

CONCLUSION

Performing physical activities in public sport center near main roads will cause a less optimal increase in aerobic and respiratory capacities compared to exercising in public sport center that is not close to main streets. The findings of this research also indicate negative effects of performing physical activities in public sport center with high level of $PM_{2.5}$ exposure on hematology profile. This particular aspect requires further studies and wider investigation with larger and representative samples such as adult and elderly via longitudinal studies.

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CONFLICT OF INTEREST

The authors state no conflict of interest.

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