



Available online at:

<https://ejournal.upi.edu/index.php/penjas/article/view/45037>DOI: <https://doi.org/10.17509/jpjo.v7i1.45037>**The Effect of Performing Exercise in Air Polluted Environments on Blood Pressure Response****Samsul Bahri\*, Yudhi Teguh Pambudi, Imam Safei, Dadan Resmana, Ilham Hindawan**

Sport Science, School of Pharmacy, Bandung Institute of Technology, Bandung, Indonesia

**Article Info***Article History :**Received February 2022**Revised March 2022**Accepted March 2022**Available online April 2022**Keywords :**Air Pollution, Blood Pressure, Exercise, PM2.5***Abstract**

Exercise has a positive impact on a person's health and fitness level. However, the benefits could be obtained if the exercise is conducted properly by avoiding the risk involved. One of the risks during exercise, especially for those in urban communities, is the difficulty in avoiding air pollution. Air pollution, especially particles with a size less than 2.5 microns (PM2.5), can be inhaled into the lungs and enter the bloodstream. The amount of air pollution inhaled will increase in the people doing exercise because the rate of breathing increases along with the increasing intensity and duration of the exercise. This may impact the blood pressure response due to the presence of foreign particles in the bloodstream. This study used a quasi-experimental method with a post-test-only comparison group approach. The research was conducted in Karawang Regency, West Java, Indonesia, and included two sites, a higher PM2.5 Concentration site, and a lower PM2.5 Concentration site. The research subjects included 22 undergraduate students with a healthy status divided into two research groups. Each group performed exercise, including 5 minutes of warm-up and 15 minutes of running at sub-maximal intensity (80–85% of HR Max) at 07.00 for five days consecutively. Blood pressure response measurements were taken immediately after exercise. This study aimed to determine the effect of regular exercise in high and low air pollution conditions (PM2.5) on the blood pressure response. The study found that regular exercise for five days in an environment with high air pollution resulted in higher systolic and diastolic arterial pressures than a regular exercise in low air pollution conditions. Thus, performing exercise in high PM2.5 air pollution conditions affects the blood pressure response. For this reason, vulnerable groups should pay attention to air pollution levels when doing exercise.

## INTRODUCTION

Physical activity or exercising regularly can positively impact increasing the level of health and fitness (Bahri et al., 2020; Brusseau et al., 2016; Ward et al., 2017). In addition, exercise can also reduce the risks of death, such as from hypertension or obesity (Galleguillos et al., 2014; Leonardo Alves Pasqua et al., 2018). Therefore, exercising regularly is recommended. The American College of Sports Medicine recommends that every person perform an exercise for at least 30 min at moderate intensity (65% of maximum pulse) two to five days a week (Riebe et al., 2015). In addition, a positive impact can be obtained if it is done correctly and avoids the risks involved (Vancini et al., 2019). When doing exercises, they should be started by warming up and avoiding movements that can cause injury. In addition, environmental conditions are a concern (Racinais et al., 2017). One environmental condition that increases the risks during exercise is air pollution (Watanabe et al., 2019). Bad air pollution conditions are challenging to avoid, especially in urban communities or near industrial areas.

One air pollution type is fine particles with a diameter of less than 2.5 microns (PM<sub>2.5</sub>). PM<sub>2.5</sub> is a mixture of solid and liquid particles suspended in the air, mostly from burning fossil fuels made from the process of heating, generating electricity, or operating motorized vehicles (Miao et al., 2019). PM<sub>2.5</sub> can be inhaled into the alveoli in the lungs and enter the bloodstream, causing health problems (Giles & Koehle, 2014). Therefore, PM<sub>2.5</sub> is a type of pollution that is currently of concern to several researchers, especially in the field of sports physiology. The amount of air pollution inhaled will increase in people who do exercise because the rate of breathing increases with increasing intensity and duration of exercise (Filomena Mazzeo & Alessandro Liccardo, 2019; Giles & Koehle, 2014). This may impact the blood pressure response due to the presence of foreign particles in the bloodstream.

Poor air pollution conditions can be found in several cities and occupied residential areas in Indonesia. The dominant use of energy in Indonesia is still environmentally unfriendly energy. Based on the 2019 National Energy Balance, 45% of energy use is in the transportation sector. In total, 99% of transportation uses fossil fuels. In addition, 58% of electricity generation comes from burning coal (Suharyati et al., 2019).

The high demand and use of conventional energy have made several cities, especially industrial cities, a source of air pollution (Haryanto, 2018; Ji et al., 2018). The areas close to air pollution sources will have worse air pollution conditions than other areas far from air pollution sources (Calderón-Garcidueñas & Villarreal-Ríos, 2017). This phenomenon can be found in the occupied residential areas of West Karawang District, West Java, Indonesia, and this area is the capital of the Regency and close to the Karawang International Industrial Center. Another area that is far from urban and industrial centres is Rengasdengklok District, West Java, Indonesia. Theoretically, these two regions should have different levels of air pollution due to differences in their distances from air pollution sources.

The contradiction between the need for regular exercise and PM<sub>2.5</sub> exposure presents an interesting challenge to balance the benefits and disadvantages, especially in areas affected by air pollution. Should exercise be limited or should it not be done in bad air pollution conditions? This has been debated in recent years. Researchers have been interested in studying the conditions of air pollution, especially in West Karawang and Rengasdengklok Districts. Are the air pollution conditions in these two regions significantly different due to the distance from air pollution sources? What are the impacts of different air pollution conditions, especially on the blood pressure response of individuals who routinely exercise in the area? This research can also be used as a basis for how the air pollution conditions in these two different regions affect human physiology, thus resulting in further research in other areas.

## METHODS

### Participants

The participants included 22 undergraduate students. The study inclusion criteria were healthy with the age of 19-22 years and had a normal body mass index. The study exclusion criteria were those with a history of chronic disease, suffered from cardiovascular disease, cardiorespiratory, including being infected with SARS-CoV-2, smoking, consuming alcohol, supplements, or drugs. All participants received direct explanations from the researcher verbally and in written form about the study's objectives, procedures, and risks. Participants were directed to sign the informed consent if

they were willing to participate in this study.

### Materials and Apparatus

The researchers used AirVisual Pro (IQAir, Switzerland), which was placed at an altitude of 1.6 m above the ground level of the study area, to measure the amount of PM<sub>2.5</sub> air pollution and additional data in the form of CO<sub>2</sub> levels, temperature, and relative humidity at the time of the study. The AirVisual Pro device was connected to the internet when retrieving data. Bodyweight was measured using an Omron HBF-375 (Omron, Japan) and height using a Metrisis Stadiometer (Solo Abadi, Indonesia). Blood pressure was measured using an Automatic Blood Pressure Monitor EM-7322 (Omron, Japan). Heart rate during exercise was monitored by Polar H10 (Polar Electro Oy, Finland).

### Procedure

This study used a quasi-experimental method with a post-test-only comparison group approach. The research location is in Karawang Regency, West Java. It consisted of two sites, i.e., the Singaperbangsa Stadium and the Cinta Lake Area, Rengasdengklok.

Before the training session, the participants filled out a form related to the age formulas based on their identity cards. Body mass index was calculated by weight in kilograms divided by height squared in meters. The participants were divided equally into two groups based on the anthropometry data obtained. The two groups of participants each occupied one of the two research sites. The participants did the exercise with 5 min of warm-up and 15 min of submaximal intensity

running (80–85% HR Max) at 07.00 am for five consecutive days at each site. Researchers monitor and ensure the heart rate is suitable during exercise. Blood pressure measurements were taken 10 min before exercise to determine the baseline blood pressure and immediately after training in each training session to determine the blood pressure response. During the measurement, participants rested in a seated position, their right arm was placed on the table parallel with the heart, and they did not talk during the measurement. During the study, the participants were asked to avoid places with high air pollution except for the study site, not to perform other heavy physical activity rather than the treatment given by the researchers, not to consume alcohol, supplements, or drugs, and to report their health conditions to the researchers.

### Data Analysis

The results are displayed in the form of means and standard deviations. The significant analysis involved an independent sample t-test. The level of significance was set at  $p < 0.05$ . Statistical analysis of this study was done using statistical software SPSS version 23 (IBM, USA).

## RESULT

Table 1 shows that the means  $\pm$  standard deviations (SD) for age, height, weight, and body mass index shows a significant difference in terms of SD. Table 2 shows that the amount of air pollution with the type of PM<sub>2.5</sub> at the Singaperbangsa Stadium site was greater

**Table 1.** Anthropometry Data

Variable	Singaperbangsa Stadium (N=11)			Cinta Lake (N=11)		
	Mean $\pm$ SD	Min	Max	Mean $\pm$ SD	Min	Max
Age (year)	20.45 $\pm$ 0.49	19.60	21.20	20.65 $\pm$ 0.56	19.80	21.50
Weight (kg)	60.09 $\pm$ 4.87	53.00	69.00	59.09 $\pm$ 3.14	54.00	63.00
Height (m)	1.68 $\pm$ 0.03	1.63	1.73	1.68 $\pm$ 0.03	1.64	1.73
BMI (kg/m <sup>2</sup> )	21.29 $\pm$ 1.17	19.49	23.05	21.02 $\pm$ 0.88	19.13	21.97

**Table 2.** Air Pollution Concentrations of the Two Sites

Pollutant	Singaperbangsa Stadium	Cinta Lake
PM <sub>2.5</sub> ( $\mu\text{g}/\text{m}^3$ )	117.90*	52.19*
CO <sub>2</sub> (ppm)	501.15*	465.73*
Temperature ( $^{\circ}\text{C}$ )	27.37	27.72
Relative Humidity (%)	76.19	76.98
Altitude (masl)	17.8	9.4

\*mean difference significant at  $p < 0.05$

PM<sub>2.5</sub>: Particulate Matter 2.5 (particulate with diameter  $<2.5$ ); CO<sub>2</sub>: Carbon Dioxide

when compared to the Cinta Lake site, while other parameters, such as CO<sub>2</sub>, temperature, relative humidity, and altitude, did not differ significantly.

At baseline, there were no significant differences for the systolic (Singaperbangsa Stadium=117.5 ± 3.5 mmHg, Cinta Lake: 116.8 ± 3.5 mmHg; P=0.17) and diastolic (Singaperbangsa Stadium=77.4 ± 0.3 mmHg, Cinta Lake=76.6 ± 0.3 mmHg; P=0.87) blood pressures. There was an increase in systolic and diastolic arterial pressure at the Singaperbangsa Stadium and Cinta Lake sites. These changes in systolic and diastolic arterial pressures were significantly different between the two experimental conditions (P<0.05). Figure 1 displays the daily blood pressure delta in the arteries as measured immediately at the end of the exercise. Data are shown as the delta mean ± standard deviation.

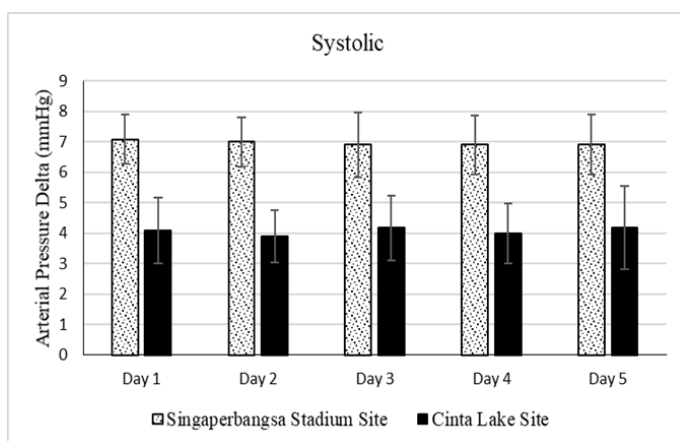


Fig 1. Daily Systolic Pressure Response

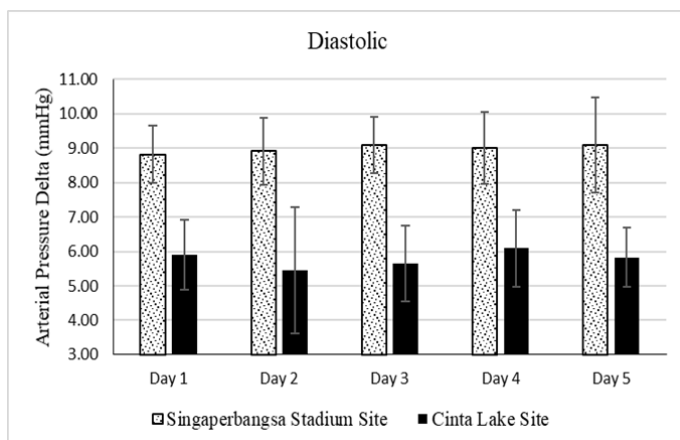


Fig 2. Daily Diastolic Pressure Response

## DISCUSSION

There was no significant difference between the two groups of participants in terms of age, weight, height, and body mass index. However, at the two research sites, there were significant differences in the concentrations of PM<sub>2.5</sub> and CO<sub>2</sub>. This difference was in the form of a higher concentration at the Singapore Stadium. This was because the Singapore Stadium is relatively closer to several industrial areas, which are sources of air pollution. There were no significant differences for other parameters such as temperature, humidity, and altitude at the two research sites.

Our research shows that regular exercise for five days in an environment with higher air pollution resulted in higher systolic and diastolic arterial pressure than in the lower air pollution conditions. In addition, there was a significant change in the blood pressure response to the two air pollution conditions for each of the five days. However, the results of the blood pressure response tended to be stable. The results of this study indicate a better arterial pressure response while doing physical activity or exercising in areas under lower air pollution conditions. The results of this study are relevant to previous studies that showed that air pollution affects an increase in blood pressure during polluted conditions (Dong et al., 2013; Giorgini et al., 2016; Leonardo A. Pasqua et al., 2020; Zeng et al., 2017).

These findings suggest that doing physical activity or exercising in a high PM<sub>2.5</sub> air pollution condition affects the blood pressure response, although individuals with a healthy status are less affected. The negative effect caused by air pollution, especially PM<sub>2.5</sub>, in occupied residential areas, should not be neglected. It should be expected because exercising can increase the air ventilation rate, which can cause air pollution to be inhaled into the alveoli in the lungs and enter the bloodstream (Marmett et al., 2020; Leonardo A. Pasqua et al., 2020; Leonardo Alves Pasqua et al., 2018; Xie et al., 2021). It is a concern for vulnerable groups. The blood pressure increase caused by PM<sub>2.5</sub> maybe even more dangerous.

## CONCLUSION

Our results indicate a need to control air pollutants globally, especially in Indonesia. In addition, we need to check the air pollution conditions regularly and report it to the public as consideration for doing activities or exercising. Therefore, everyone should consider the air pollution concentration in the environment before exercising or doing physical activity. Moreover, this needs to be a concern for some vulnerable groups, such as the elderly and those suffering from hypertension.

## CONFLICT OF INTEREST

The authors declared no conflict of interest.

## REFERENCES

- Bahri, S., Safei, I., & Satriyo Tomo, H. (2020). Dampak berolahraga di area yang terpapar oleh polusi udara The Effect of Exercising in an Area Exposed to Air Pollution. *Jurnal Penelitian Pembelajaran*, 6(3), 588–598. [https://doi.org/10.29407/js\\_unpgri.v6i3.14708](https://doi.org/10.29407/js_unpgri.v6i3.14708)
- Brusseau, T. A., Hannon, J., & Burns, R. (2016). The effect of a comprehensive school physical activity program on physical activity and health-related fitness in children from low-income families. *Journal of Physical Activity and Health*, 13(8), 888–894. <https://doi.org/10.1123/jpah.2016-0028>
- Calderón-Garcidueñas, L., & Villarreal-Ríos, R. (2017). Living close to heavy traffic roads, air pollution, and dementia. *The Lancet*, 389(10070), 675–677. [https://doi.org/10.1016/S0140-6736\(16\)32596-X](https://doi.org/10.1016/S0140-6736(16)32596-X)
- Dong, G. H., Qian, Z. M., Xaverius, P. K., Trevathan, E., Maalouf, S., Parker, J., Yang, L., Liu, M. M., Wang, D., Ren, W. H., Ma, W., Wang, J., Zelicoff, A., Fu, Q., & Simckes, M. (2013). Association between long-term air pollution and increased blood pressure and hypertension in China. *Hypertension*, 61(3), 578–584. <https://doi.org/10.1161/HYPERTENSIONAHA.111.00003>
- Filomena Mazzeo, & Alessandro Liccardo. (2019). RESPIRATORY RESPONSES TO EXERCISE IN SPORT. *Sport Science*, 12(1), 49–52.
- Galleguillos, M. F., Céspedes, C., & Saa, D. (2014). Hypertension and chronic kidney disease. *Advances in Hypertension Research*, 185–225.
- Giles, L. V., & Koehle, M. S. (2014). The health effects of exercising in air pollution. In *Sports Medicine* (Vol. 44, Issue 2, pp. 223–249). <https://doi.org/10.1007/s40279-013-0108-z>
- Giorgini, P., Di Giosia, P., Grassi, D., Rubenfire, M., D. Brook, R., & Ferri, C. (2016). Air Pollution Exposure and Blood Pressure: An Updated Review of the Literature. *Current Pharmaceutical Design*, 22(1), 28–51. <https://doi.org/10.2174/1381612822666151109111712>
- Haryanto, B. (2018). Climate Change and Urban Air Pollution Health Impacts in Indonesia. *Springer Climate*, 215–239. [https://doi.org/10.1007/978-3-319-61346-8\\_14](https://doi.org/10.1007/978-3-319-61346-8_14)
- Ji, X., Yao, Y., & Long, X. (2018). What causes PM2.5 pollution? Cross-economy empirical analysis from socioeconomic perspective. *Energy Policy*, 119, 458–472. <https://doi.org/10.1016/j.enpol.2018.04.040>
- Marmett, B., Carvalho, R. B., Dorneles, G. P., Nunes, R. B., & Rhoden, C. R. (2020). Should I stay or should I go: Can air pollution reduce the health benefits of physical exercise? *Medical Hypotheses*, (June), 109993. <https://doi.org/10.1016/j.mehy.2020.109993>
- Miao, Z., Baležentis, T., Shao, S., & Chang, D. (2019). Energy use, industrial soot and vehicle exhaust pollution—China's regional air pollution recognition, performance decomposition and governance. *Energy Economics*, 83, 501–514. <https://doi.org/10.1016/j.eneco.2019.07.002>
- Pasqua, Leonardo A., Damasceno, M. V., Cruz, R., Matsuda, M., Martins, M. A. G., Marquezini, M. V., Lima-Silva, A. E., Saldiva, P. H. N., & Bertuzzi, R. (2020). Exercising in the urban center: Inflammatory and cardiovascular effects of prolonged exercise under air pollution. *Chemosphere*, 254. <https://doi.org/10.1016/j.chemosphere.2020.126817>
- Pasqua, Leonardo Alves, Damasceno, M. V., Cruz, R., Matsuda, M., Martins, M. G., Lima-Silva, A. E., Marquezini, M., Saldiva, P. H. N., & Bertuzzi, R. (2018). Exercising in air pollution: The cleanest versus dirtiest cities challenge. *International Journal of Environmental Research and Public Health*, 15(7). <https://doi.org/10.3390/ijerph15071502>
- Racinais, S., Cocking, S., & Périard, J. D. (2017). Sports and environmental temperature: From warming-up to heating-up. In *Temperature* (Vol. 4, Issue 3, pp. 227–257). Routledge. <https://doi.org/10.1080/23328940.2017.1356427>
- Riebe, D., Franklin, B. A., Thompson, P. D., Garber, C. E., Whitfield, G. P., Magal, M., & Pescatello, L. S. (2015). Updating ACSM's recommendations for exercise preparticipation health screening. *Medicine and Science in Sports and Exercise*, 47(11), 2473–2479. <https://doi.org/10.1249/MSS.0000000000000664>
- Suharyati, Pambudi, S. H., Wibowo, J. L., & Pratiwi, N. I. (2019). *Indonesia Energy Outlook 2019*.
- Vancini, R. L., Nikolaidis, P. T., de Lira, C. A. B., Vancini-Campanharo, C. R., Viana, R. B., Andrade, M. D. S., Rosemann, T., & Knechtel, B. (2019). Prevention of sudden death related to sport: The science of basic life support—from theory to practice. In

- Journal of Clinical Medicine (Vol. 8, Issue 4). MDPI. <https://doi.org/10.3390/jcm8040556>
- Ward, J. K., Hastie, P. A., Wadsworth, D. D., Foote, S., Brock, S. J., & Hollett, N. (2017). A Sport Education Fitness Season's Impact on Students' Fitness Levels, Knowledge, and In-Class Physical Activity. *Research Quarterly for Exercise and Sport*, 88(3), 346–351. <https://doi.org/10.1080/02701367.2017.1321100>
- Watanabe, N. M., Yan, G., Soebbing, B. P., & Fu, W. (2019). Air pollution and attendance in the Chinese super league: Environmental economics and the demand for sport. *Journal of Sport Management*, 33(4), 289–302. <https://doi.org/10.1123/JSM.2018-0214>
- Xie, W., You, J., Zhi, C., & Li, L. (2021). The toxicity of ambient fine particulate matter (PM<sub>2.5</sub>) to vascular endothelial cells. In *Journal of Applied Toxicology* (Vol. 41, Issue 5, pp. 713–723). John Wiley and Sons Ltd. <https://doi.org/10.1002/jat.4138>
- Zeng, X. W., Qian, Z. (Min), Vaughn, M. G., Nelson, E. J., Dharmage, S. C., Bowatte, G., Perret, J., Chen, D. H., Ma, H., Lin, S., de Foy, B., Hu, L. W., Yang, B. Y., Xu, S. L., Zhang, C., Tian, Y. P., Nian, M., Wang, J., Xiao, X., ... Dong, G. H. (2017). Positive association between short-term ambient air pollution exposure and children blood pressure in China—Result from the Seven Northeast Cities (SNEC) study. *Environmental Pollution*, 224, 698–705. <https://doi.org/10.1016/j.envpol.2017.02.054>