DOI: 10.14744/ejmi.2023.61426
EJMI 2023;7(3):259–266

Research Article

Investigation of Short-Term Health Effects of Air Pollution in Türkiye with E-Nabız Sensor Data

Suayip Birinci,[1] Fikriye Yilmaz,[2] Simten Malhan[3]

[1]Health Ministry of Türkiye, Ankara, Türkiye
[2]Department of Healthcare Management, Baskent University, Ankara, Türkiye
[3]Guven Healthcare Group, Ankara, Türkiye

Abstract

Objectives: The aim of the study is to reveal the short-term health effects of exposure to air pollution (respiratory rate, heart rate and sleep duration) through sensor data.

Methods: The average number of daily admissions of asthma and COPD patients with ICD 10 J41, J43, J44 and J45 diagnosis codes obtained from the Ministry of Health E-Nabız system in 1 month before the date of increase in air pollution and the average number of daily admissions in 1 month after that date were taken on the basis of age group, clinic and province.

Results: Analyses were conducted on 1,040,235 people reached through the E-Nabız sensor data. 54.2% of the participants were male, 69.4% were aged between 25-39 years, 49.9% lived in the Marmara Region and 92.7% lived in urban areas. The mean respiratory rate of the participants was 18.01±1.345 per minute, and the mean respiratory rate was higher in women, those younger than 25 years of age ($p<0.05$). The mean heart rate of the participants was 84.54±3.722 per minute, and the mean heart rate was higher in women, those younger than 25 years of age ($p<0.05$). The mean sleep duration of the participants in the study was calculated as 403.83±42.570 minutes, and women, those younger than 25 years and older than 65 years ($p<0.05$).

Conclusion: The design of the study based on the analysis of sensor data made it possible to evaluate the short-term health effects of air pollution at the national level for the first time in Türkiye.

Keywords: Air Pollution, E-Nabız, Sensor data, Physiological Parameters

Cite This Article: *Birinci S, Yilmaz F, Malhan S. Investigation of Short-Term Health Effects of Air Pollution in Türkiye with E-Nabız Sensor Data. EJMI 2023;7(3):259–266.*

Air pollution is the pollution of the indoor or outdoor environment by any chemical, physical or biological agent that alters the natural properties of the atmosphere. Household combustion appliances, motor vehicles, industrial plants and forest fires are common sources of air pollution. Major pollutants of public health concern include particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulphur dioxide.[1] WHO data show that almost the entire global population (99 per cent) breathes air containing high levels of pollutants that exceed WHO guideline limits, with low- and middle-income countries experiencing higher levels of exposure.[2] Outdoor and indoor air pollution can cause acute and chronic respiratory diseases and other diseases such as stroke, heart disease, lung cancer and is recognised as one of the main risk factors for death.[3-5] WHO estimates that globally, air pollution is responsible for about 7 million premature deaths annually from ischaemic heart disease, stroke,

Address for correspondence: Suayip Birinci, MD. Türkiye Sağlık Bakanlığı, Ankara, Türkiye
Phone: +90 312 585 1000 **E-mail:** suayipbirinci@yahoo.com
Submitted Date: August 16, 2023 **Accepted Date:** September 15, 2023 **Available Online Date:** September 19, 2023

chronic obstructive pulmonary disease and lung cancer, as well as acute respiratory infections such as pneumonia, which mainly affect children in low- and middle-income countries.[6,7] Air pollution is also a threat to the public health economy as it imposes very serious health costs, accounting for 6.1 per cent of global gross domestic product (more than US$8 trillion in 2019).[8]

According to the World Air Pollution Report, Türkiye has become the 46th country with the most polluted air in the World.[9] The Black Report published by the Right to Clean Air Platform reported that approximately 42 thousand people lost their lives due to diseases caused by air pollution in 2021.[10] Cardiovascular diseases, chronic respiratory diseases, cancers, diabetes and chronic kidney diseases, respiratory infections and tuberculosis are among the diseases caused by air pollution. It is also stated that air pollution affects mental health and neurological health by increasing the severity of psychiatric diseases and decreasing sleep quality and duration.[10]

In many national and international studies in the literature, it is seen that health risks from air pollution are generally presented in terms of attributable mortality, morbidity, years of life lost, life years adjusted for disability, or change in life expectancy attributable to absolute exposure to air pollution or change in exposure.[11] However, studies on short-term health effects of air pollution such as respiratory rate, heart rate and sleep duration are very limited.[3,6,11] In this study, short-term (minutes to several hours) effects of exposure to air pollution were attempted to be determined at a personal level based on continuous monitoring of the subjects using wearable sensors. These sensors send data wirelessly to a mobile phone, from where it is transmitted with time tags to a cloud-based server for storage, editing and analysis. With the development of wearable sensors in health informatics, it has become more possible to promote healthy living and early diagnosis of diseases by monitoring the health of individuals.[6,12-14] In this context, this study was carried out to examine the short-term health effects of exposure to air pollution (respiratory rate, heart rate and sleep duration) with sensor data.

Methods

The study was designed in an analytical and cross-sectional model to reveal the short-term effects of air pollution on health. In the study, data on air pollution levels were collected weekly on a provincial basis between 28.10.2022-28.05.2023 using the web service of the Ministry of Environment, Urbanisation and Climate Change. For the same dates, the average number of daily admissions of asthma and COPD patients with ICD 10 J41, J43, J44 and J45 diagnosis codes obtained from the Ministry of Health E-Nabız system in 1 month before the date of increase in air pollution and the average number of daily admissions in 1 month after that date were taken on the basis of age group, clinic and province. The physiological parameters of the study were obtained from the Ministry of Health MIZ System (Spatial Business Intelligence System) as sleep duration, heart rate and respiratory rate on the basis of province, rural status, age group and gender between 01.01.2022-28.05.2023. Air pollution data on the basis of province and week were matched with the number of applications of asthma and COPD patients and physiological parameters. In the study, the data of 1,040,235 individuals for whom air pollution and physiological parameters were matched on a weekly basis were analysed. Data were analysed using IBM SPSS Statistics 22.0 package programme. While the outcome variable of the study was considered as physiological parameters, gender, age group, province, region, rural status and air pollution level were considered as independent variables. Air pollution levels, explanations and ranges of these levels are shown below and air pollution levels in the data were determined accordingly. In province-based comparisons, the worst level of the province between the specified dates was taken as the basis.

Medium (50-100) Air quality is favourable and groups sensitive to air pollution may be moderately affected, Fair weather for outdoor sports, Fair weather for cycling, Fair weather for outdoor walking, Fair weather for outdoor picnics.

Sensitive (100-150) Health effects may occur for sensitive groups. The general public is not expected to be affected, Not good weather for outdoor sports, Not good weather for cycling, Not good weather for outdoor walking, Not good weather for outdoor picnics.

Unhealthy (150-200) Vulnerable groups may experience serious health problems, General public likely to experience some health effects, Bad weather for outdoor sports, Bad weather for cycling, Bad weather for hiking outdoors, Bad weather for picnics outdoors.

Bad (200-300) The entire population is likely to be affected by air pollution and vulnerable groups should restrict outdoor activities, Very bad weather for outdoor sports, Very bad weather for cycling, Very bad weather for outdoor walking, Very bad weather for outdoor picnics

Dangerous (300-500) Everyone may experience serious health effects, Outdoor activities should be avoided, Never do outdoor sports, Never cycle, Never hike outdoors, Never picnic outdoors.

Descriptive statistics, chi-square analysis, independent sample t-test, one-way analysis of variance were used to analyse the data. In order to determine whether the mean sleep duration, heart rate and respiratory rate of the participants differed according to gender, age group, rural area, region and air pollution level, Independent Sample T-Test was performed for variables with two groups and One-Way Analysis of Variance was performed for variables with three or more groups. Chi-square analysis was performed to determine the differences in the general characteristics of the participants according to the level of air pollution. The change in the number of visits to clinics by asthma/COPD patients according to the increase in air pollution level was compared by Paired Sample T-test. Statistical significance level p<0.05 was accepted in the evaluations.

Findings

The distribution of the participants according to their general characteristics is shown in Table 1. 54.2% of the participants were male, 69.4% were between 25-39 years of age, 49.9% lived in the Marmara Region and 92.7% lived in urban areas. The mean respiratory rate of the participants was 18.01±1.345 per minute, and it was determined that the mean respiratory rate was higher in women, those younger than 25 years of age, those living in rural areas, and those living in the Southeastern and Eastern Anatolia regions (p<0.05). The mean heart rate of the participants was 84.54±3.722 per minute, and it was observed that the mean heart rate was higher in women, those younger than 25 years of age, those living in urban areas, and those living in the Mediterranean and Marmara regions (p<0.05). The mean sleep duration of the participants in the study was calculated as 403.83±42.570 minutes (≈6.73 hours), and it was determined that women, those younger than 25 years and older than 65 years, those living in urban areas, and those living in the Aegean and Marmara regions slept more on average (p<0.05).

The general characteristics of the participants according to air pollution exposure level are shown in Table 2. According to the air pollution and physiological parameters matching data, 89.4% of the participants were exposed to moderate air pollution. It was determined that there were more people exposed to air pollution at "sensitive" level among males, 40-64 years old, those living in urban areas and those living in Aegean and Central Anatolia (p<0.05).

Table 3 shows the mean physiological parameters of the

Table 1. General Characteristics and Mean Physiological Parameters of the Participants

	n (%)	Average Respiratory Rate	Mean Heart Rate	Average Sleep Duration
Total	1040235	18.01±1.345	84.54±3.722	403.83±42.570
Gender				
Female	475964 (45.7)	18.12±1.263	85.43±3.511	412.86±39.070
Male	564271 (54.2)	17.91±1.404	83.73±3.723	396.47±43.866
p		0.000*	0.000*	0.000*
Age				
<25	112771 (10.8)	18.43±1.609	88.60±3.491	410.02±49.980
25-39	721967 (69.4)	18.07±1.151	85.59±2.256	398.45±36.891
40-64	192593 (18.5)	17.54±1.581	82.30±2.853	406.60±43.011
>65	12904 (1.2)	17.58±2.583	76.74±4.780	426.80±61.594
p		0.000*	0.000*	0.000*
Ruralisation Status				
Rural	76109 (7.3)	18.25±2.530	84.09±5.474	397.65±71.227
City	964126 (92.7)	17.99±1.201	84.58±3.533	404.43±38.613
p		0.000*	0.000*	0.000*
Region				
Mediterranean Region	93656 (9)	18.16±1.588	84.84±3.661	402.0±47.28
Eastern Anatolia Region	21080 (2)	18,71±2.815	84.47±5.279	400.34±65.99
Aegean Region	142832 (13.7)	17.94±1.397	84.29±3.800	408.12±46.62
Southeastern Anatolia Region	30061 (2.8)	18.77±2.225	85.33±4.042	385.74±61.24
Central Anatolia Region	176571 (16.9)	18.10±1.222	83.95±3.502	403.39±96.82
Black Sea Region	56817 (5.4)	18.08±2.377	84.17±4.827	399.09±62.13
Marmara Region	519218 (49.9)	17.88±0.906	84.73±3.455	404.71±33.28
p		0.000*	0.000*	0.000*

Table 2. General Characteristics of Participants According to Level of Exposure to Air Pollution

	Air Pollution (n (%))				p
	Center	Sensitive	Unhealthy	Dangerous	
Total	333755 (89.4)	36830 (9.9)	1919 (0.5)	764 (0.2)	
Gender					
Female	162309 (89.4)	17875 (9.8)	956 (0.5)	334 (0.2)	0.035
Male	171446 (89.4)	18955 (9.9)	963 (0.5)	430 (0.2)	
Age					
<25	37267 (89.4)	4115 (9.9)	176 (0.4)	105 (0.3)	0.000
25-39	185730 (89.6)	20107 (9.7)	1110 (0.5)	453 (0.2)	
40-64	101997 (89.3)	11435 (10.0)	578 (0.5)	196 (0.2)	
>65	8761 (87.6)	1173 (11.7)	55 (0.6)	10 (0.1)	
Ruralisation Status					
Rural	23712 (90.6)	2265 (8.7)	71 (0.3)	131 (0.5)	0.000
City	310043 (89.3)	34565 (10)	1848 (0.5)	633 (0.2)	
Region					
Mediterranean Region	29674 (92.9)	1975 (6.2)	144 (0.5)	158 (0.5)	0.000
Eastern Anatolia Region	5979 (96.2)	164 (2.6)	64 (1.0)	6 (0.1)	
Aegean Region	39838 (73.5)	12569 (23.2)	1459 (2.7)	346 (0.6)	
Southeastern Anatolia Region	7763 (92.2)	655 (7.8)	0 (0.0)	0 (0.0)	
Central Anatolia Region	45979 (70.0)	19172 (29.2)	252 (0.4)	245 (0.4)	
Black Sea Region	18374 (98.4)	282 (1.5)	0 (0.0)	9 (0.0)	
Marmara Region	186148 (98.9)	2013 (1.1)	0 (0.0)	0 (0.0)	

Table 3. Mean Physiological Parameters According to Air Pollution Categories

Air Pollution	Mean Respiratory Rate (min)	Mean Heart Rate (min)	Average Sleep Duration (min)
Center	17.73±1.258	83.95±3.371	384.94±67.202
Sensitive	17.92±0.992	83.86±3.600	404.47±37.559
Unhealthy	17.93±1.203	83.97±3.401	
Dangerous	18.06±1.542	84.51±3.697	411.96±28.857
p	0.000*	0.000*	0.000*

participants according to the level of air pollution. As seen in the table, as the level of air pollution increases, mean respiratory rate, mean heart rate and mean sleep duration increase statistically significantly ($p<0.05$).

Figures 1-3 shows the distribution of provinces in terms of physiological parameters according to air pollution levels in Türkiye. Since the air pollution levels of the provinces may vary according to the weeks, mapping was made based on the worst measurement value between 28.10.2022-28.05.2023. As shown in Map 1, the lowest average respiratory rate in Türkiye is among those living in Artvin and the highest is among those living in Iğdır. According to the provinces, as the air pollution level increases, the average respiratory rate increases statistically significantly ($p<0.05$). As seen in Map 2, Igdir is the province with the highest heart rate, while Bitlis is the province with the lowest average heart rate. According to the provinces, as the air pollution level increases, the average heart rate also increases statistically significantly ($p<0.05$). As seen in Map 3, the province with the least average sleep time is Kilis with an average of 5.8 hours, while those living in Ardahan sleep 1 hour more on average. According to the provinces, as the level of air pollution increases, the average sleep duration increases statistically significantly ($p<0.05$).

Figure 4 shows the clinics with ICD 10 J41, J43, J44 and J45 diagnosis codes obtained from the Ministry of Health E- Nabız system between 28.10.2022-28.05.2023 and the clinics with an increase in the number of daily average admissions of asthma and COPD patients due to the increase in air pollution. As can be seen in Figure 4, the average daily admissions of asthma/COPD patients in internal medicine, pulmonology, ophthalmology and paediatric infectious

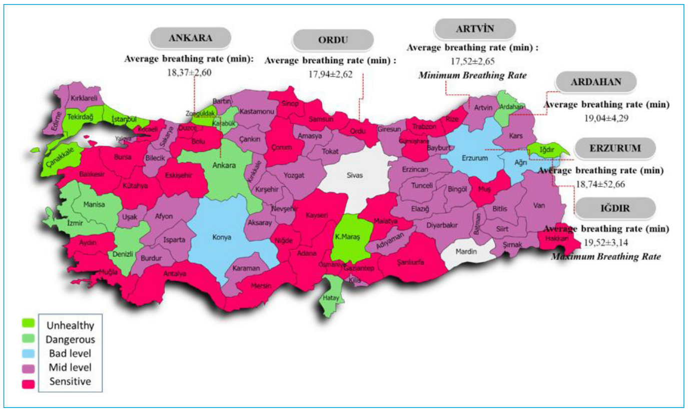

Figure 1. Provinces with the Highest and Lowest Average Respiratory Rate According to Air Pollution Level in Türkiye.

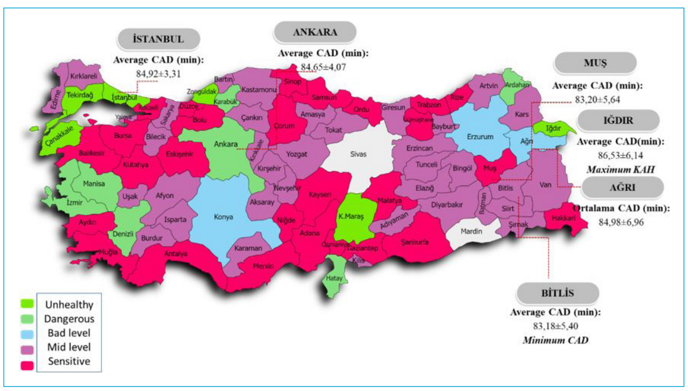

Figure 2. Provinces with the Highest and Lowest Average Heart Rate (HR) According to Air Pollution Levels in Türkiye.

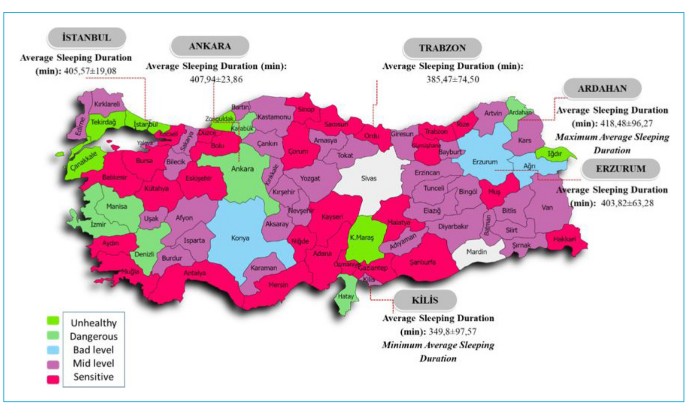

Figure 3. Provinces with the Highest and Lowest Average Sleep Duration According to Air Pollution Levels in Türkiye.

diseases increased statistically significantly ($p<0.05$) due to the increase in air pollution levels. When the increases in the average number of admissions were analysed in terms of general characteristics;

- The increases in internal medicine clinics were significant in all regions except Marmara Region and in all age groups except 20-34 years old,
- The increases in Chest Diseases were significant in all regions except Marmara Region and in all age groups except 0-9 years and 15-44 years,
- Increases in eye diseases were more significant in those living in the Eastern, Southeastern and Central Anatolia regions and in those aged 45-84 years,
- The increases in paediatric infectious diseases were found to be significant in all regions except South-eastern Anatolia and in the 0-14 age group.

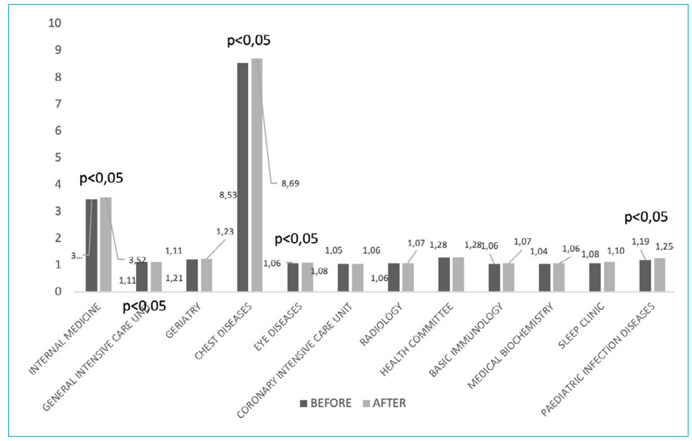

Figure 4. Clinics where an increase in the admissions of asthma/COPD patients was observed due to the increase in air pollution.

Discussion

In this study, which was conducted for the first time using sensor data to evaluate the short-term effects of air pollution on health, it was concluded that respiratory rate, heart rate and sleep duration increased as the air pollution level increased. In addition, it was determined that the applications of individuals with COPD and asthma to internal medicine, pulmonology, ophthalmology and paediatric infectious diseases clinics increased due to the increase in air pollution level. In line with the findings of the study, it is possible to make the following conclusions.

The first of the main results of the study is that the average respiratory rate of individuals increases as the air pollution level increases. Respiratory rate is one of the basic vital signs of the human body; it is defined as the rate at which breathing occurs, which is regulated and controlled by the respiratory centre of the brain, and is usually measured in breaths per minute. The rate, pattern and depth of breathing indicates how well the body is working to deliver oxygen to organs and tissues. There is considerable evidence to suggest that an abnormal respiratory rate is a harbinger of potentially serious clinical events.[13,15] Developments in health informatics have made it possible to monitor vital indicators such as respiratory rate outside clinical settings and for healthy individuals.[12] In addition to many individual factors such as age, gender and genetics that affect respiratory rate, global events such as air pollution and climate crisis have also started to be taken into consideration as an important determinant of diseases. The increase in respiratory rate as an indicator of increased oxygen demand of individuals, which is revealed by the findings of the study, has also been demonstrated by studies[11,13,14] with clinical data and a small number of sensor data as an important effect of air pollution.

In the study, it was concluded that the mean heart rate increased as the level of air pollution increased. It has been proven by clinical/epidemiological studies that environmental risk factors such as air pollution increase cardiological morbidity and mortality.[5,15,16] Heart rate (pulse rate) is the frequency of the heartbeat measured by the number of contractions per minute. Heart rate can vary according to the physical needs of the body, including the need to take in oxygen and remove carbon dioxide, and can vary from person to person due to different factors such as age, gender and physical structure. In addition, it is considered normal to observe changes in heart rate due to different reasons such as genetics, physical activity, stress and psychological state, diet, drug use, hormonal status, disease and environment. Studies [3,18,16,14,19] explain this with the fact that the interaction between air pollutants and lung receptors may cause inflammation in the lungs and reflex responses in the autonomic nervous system, leading to an increase in heart rate.[20]

Finally, it was found that the average sleep duration increased as the level of air pollution increased. In addition to many negative health consequences of air pollution, recent studies have focused on the relationship between air pollution and sleep quality and sleep disorders. Although an evaluation on the sensor data used in this study was not found in the literature, survey-based studies have found that air pollution increases sleep duration but decreases sleep quality.[21, 22] There is no definite explanation regarding the biological mechanisms by which air pollution affects sleep. However, various toxicology studies suggest that reduced sunlight caused by air pollution and its toxic components may play an important role in the adverse effects of air pollution on sleep.[23] Some studies have revealed that higher concentrations of air pollution, such as PM, prevent sunlight from reaching the Earth's surface. However, exposure to sunlight has been proven to increase the production of melatonin, a hormone linked to better sleep.[24] In addition, there are also studies showing that air pollution such as PM2.5 and PM1 can penetrate the placenta and the brain-blood barrier through inhalation, ingestion and dermal contact pathways, affecting the lymphatic and central neurological systems after being translocated in the blood and ultimately affecting sleep.[25, 26] Another possible mechanism is that ambient particles may exacerbate upper airway obstruction and increase the likelihood of apnoea and hypoxia, both of which affect sleep.[27, 28]

An important risk group for air pollution is people with asthma or chronic obstructive pulmonary disease (COPD). Numerous studies have shown a positive association between exposure to air pollutants and respiratory problems, including asthma exacerbations.[29-32] The findings of the study regarding the increase in service utilisation of asthma/COPD patients also support these claims.

Conclusion

The design of the study based on the analysis of sensor data made it possible to evaluate the short-term health effects of air pollution at the national level for the first time in Türkiye. In addition, the lack of a study that objectively evaluates the relationship between air pollution and sleep through wearable technologies in international studies is one of the contributions to the literature. Combining studies that examine the effects of air pollution on diseases with clinical-based studies with such studies that examine the effects of air pollution on healthy populations on a larger scale through sensor data will enable us to focus on a more realistic and permanent solution to air pollution. Considering that more objective results can be achieved with sensor data, it is thought that analyses that will include sleep quality in future studies may be more useful. The digital personal health database launched by the Ministry of Health in 2015 processes and stores the data of approximately 75 million people living in Türkiye [33]. Thanks to this database, when harmonised with wearable technologies, patients can be instantly monitored, intervened and their chronic diseases can be managed in an ideal way. Digital health technology E-nabiz is a valuable national move that will be instrumental in the production of accurate and evidence-based health policies and the rational use of resources in Türkiye. In order for the system to provide better service to all citizens, more individuals need to harmonise their personal health records with wearable technologies, and for this purpose, public awareness should be raised.

Disclosures

Ethics Committee Approval: Ministry of Health, Approval code: Z-67523305-0-99-21 8808408, Date: 26.06.2023.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – S.B.; Design – S.B.; Supervision – F.Y.; Materials – S.B.; Data collection &/or processing – S.B.; Analysis and/or interpretation – F.Y.; Literature search – S.M.; Writing – S.B.; Critical review – S.M.

References

1. World Health Organization Guidance on Air Pollution and Health. Available [Online]: https://www.who.int/tools/compendiumon-health-and-environment/air-pollution-and-health (Accessed on 13 September 2021).
2. Who (2018 a). "Ambient air pollution: Health impacts," World Health Organization, 25-Sep-2018. [Online]. Available: https://www.who.int/airpollution/ambient/health-impacts/en/. (Accessed on 19.07.2023)
3. Pieters N, Plusquin M, Cox B, Kicinski M, Vangronsveld J, Nawrot TS. An epidemiological appraisal of the association between heart rate variability and particulate air pollution: a meta-analysis. Heart 2012;98:1127–35.
4. Al-Kindi SG, Brook RD, Biswal S, Rajagopalan S. Environmental determinants of cardiovascular disease: lessons learned from air pollution. Nature Reviews Cardiology 2020; 17:656–72.
5. Alahmad B, Khraishah H, Althalji K, Borchert W, Al-Mulla F, Koutrakis P. Connections Between Air Pollution, Climate Change, and Cardiovascular Health. Canadian Journal of Cardiology 2023.
6. K. Hu, Y. Wang, A. Rahman and V. Sivaraman, "Personalising pollution exposure estimates using wearable activity sensors," 2014 IEEE Ninth International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), Singapore, 2014, pp. 1-6.
7. WHO (2018 b). "Air pollution," World Health Organization, 23-Nov-2018. [Online]. Available: https://www.who.int/airpollution/en/ (19.07.2023)
8. WHO (2023). "Air pollution: The invisible health threat", 12-July-2023. [Online]. Available: https://www.who.int/newsroom/feature-stories/detail/air-pollution--the-invisible-health-threat (Accessed on 19.07.2023)
9. IQAir. World Air Quality Report 2021. 2022. [Online]. https://drive.google.com/file/d/14bkaeeEdStuerVXLMCb2iOc4kY2USIr6/view
10. Temiz Hava Hakkı Platformu. Kara Rapor 2022 Hava Kirliliği ve Sağlık Etkileri. [Online] https://www.temizhavahakki.com/wp-content/uploads/2022/09/Kara-Rapor-2022-Son27082022.pdf (Accessed on 18.07.2023)
11. Arvind, D. K., & Maiya, S. Sensor data-driven analysis for identification of causal relationships between exposure to air pollution and respiratory rate in asthmatics. ArXiv preprint; 2023. ArXiv:2301.06300.
12. Aliverti A. Wearable technology: role in respiratory health and disease. Breathe 2017;13: e27–e36.
13. Liu H, Allen J, Zheng D, Chen F. Recent development of respiratory rate measurement technologies. Physiological Measurement 2019; 40:07TR01.
14. Chaix B, Bista S, Wang L, Benmarhnia T, Dureau C, Duncan DT. MobiliSense cohort study protocol: do air pollution and noise exposure related to transport behaviour have short-term and longer-term health effects in Paris, France? BMJ Open 2022;12: e048706.
15. Ruidavets J-B. Increased resting heart rate with pollutants in a population based study. Journal of Epidemiology & Community Health 2005; 59:685–93.
16. Huang C, Tang M, Li H, Wen J, Wang C, Gao Y, et al. Particulate matter air pollution and reduced heart rate variability: How the associations vary by particle size in Shanghai, China. Ecotoxicology and Environmental Safety 2021; 208:111726.
17. Yuan, George, Nicole A. Drost, and R. Andrew McIvor. "Respiratory rate and breathing pattern." McMaster Univ. Med. J. 2013;10: 23-25.
18. Fiordelisi A, Piscitelli P, Trimarco B, Coscioni E, Iaccarino G, Sorriento D. The mechanisms of air pollution and particulate matter in cardiovascular diseases. Heart Failure Reviews 2017; 22:337–47.
19. Pangaribuan, Mandroy, et al. "Effect of short-term exposures to traffic air pollution and temperature on heart rate among healthy female students during commuting." Atmospheric Pollution Research 14.1 2023;101631.
20. Mallach G, Shutt R, Thomson EM, Valcin F, Kulka R, Weichenthal S. Randomized Cross-Over Study of In-Vehicle Cabin Air Filtration, Air Pollution Exposure, and Acute Changes to Heart Rate Variability, Saliva Cortisol, and Cognitive Function. Environmental Science & Technology 2023; 57:3238–47.
21. Yu, Chen, Paige Gordon, Yu, Wang. The Association between Air Pollution and Sleep Duration: A Cohort Study of Freshmen at a University in Beijing, China. International Journal of Environmental Research and Public Health 2019; 16:3362.
22. Liu J, Wu T, Liu Q, Wu S, Chen J-C. Air pollution exposure and adverse sleep health across the life course: A systematic review. Environmental Pollution 2020; 262:114263.
23. Liu F, Zhou F, Zhang K, Wu T, Pan M, Wang X, et al. Effects of air pollution and residential greenness on sleep disorder: A 8-year nationwide cohort study. Environmental Research 2023; 220:115177.
24. Obayashi K, Saeki K, Iwamoto J, Okamoto N, Tomioka K, Nezu S, et al. Positive Effect of Daylight Exposure on Nocturnal Urinary Melatonin Excretion in the Elderly: A Cross-Sectional Analysis of the HEIJO-KYO Study. The Journal of Clinical Endocrinology & Metabolism 2012; 97:4166–73.
25. Calderón-Garcidueñas L, Ayala A. Air Pollution, Ultrafine Particles, and Your Brain: Are Combustion Nanoparticle Emissions and Engineered Nanoparticles Causing Preventable Fatal Neurodegenerative Diseases and Common Neuropsychiatric Outcomes? Environmental Science & Technology 2022; 56:6847–56.
26. Jankowska-Kieltyka M, Roman A, Nalepa I. The Air We Breathe: Air Pollution as a Prevalent Proinflammatory Stimulus Contributing to Neurodegeneration. Frontiers in Cellular Neuro-

science 2021;15.

27. Losacco C, Perillo A. Particulate matter air pollution and respiratory impact on humans and animals. Environmental Science and Pollution Research 2018; 25:33901–10.
28. Tenero L, Piacentini G, Nosetti L, Gasperi E, Piazza M, Zaffanello M. Indoor/outdoor not-voluptuary-habit pollution and sleep-disordered breathing in children: a systematic review. Translational Pediatrics 2017; 6:104–10.
29. McConnell R, Berhane K, Gilliland F, London SJ, Vora H, Avol E, et al. Air pollution and bronchitic symptoms in Southern California children with asthma. Environmental Health Perspectives 1999; 107:757–60.
30. Wyler, Catherine, et al. "The Swiss Study on Air Pollution and Lung Diseases in Adults (SAPALDIA) Team, et al. Exposure to motor vehicle traffic and allergic sensitization." Epidemiology 11, 2000;450-456.
31. Salvi S. Health effects of ambient air pollution in children. Paediatric Respiratory Reviews 2007; 8:275–80.
32. Kurt OK, Zhang J, Pinkerton KE. Pulmonary health effects of air pollution. Current Opinion in Pulmonary Medicine 2016; 22:138–43.
33. Birinci Ş. A Digital Opportunity for Patients to Manage Their Health: Türkiye National Personal Health Record System (The e-Nabız). Balkan Medical Journal 2023; 40:215–21.