Environmental strategies to reduce air pollution and their potential impact on heart failure prevention

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Abstract. This research article explores different strategies to reduce air pollution and their potential impact on heart failure prevention. The article reviews current research regarding the effects of atmospheric pollution on cardiovascular health. The authors analyze the role of traffic emissions, industrial processes, and other sources of pollution in the development of heart failure and consider the effectiveness of various environmental strategies in reducing pollution levels. The potential public health benefits of implementing such strategies and possible ways to implement them are also discussed. This article aims to contribute to the development of effective interventions to protect the environment and reduce the risk of heart failure.

1 Introduction

The development of primary school-aged boys and girls exhibits unique characteristics, as highlighted in Ilyin's review, which underscores the asynchronous nature of their development. While boys may show advancement in certain periods, girls may excel in others. Despite minor gender differences in various functional systems during the school period, electrocardiographic studies have revealed subtle variances in heart electrical activity between boys and girls.

However, research into gender differences in heart rate variability (HRV) parameters among primary school-aged children remains limited, particularly regarding the influence of academic success on the severity of these differences. Exploring such aspects not only enhances theoretical understanding of gender-related variations in heart function and regulatory mechanisms but also sheds light on the broader influence of academic achievement on physiological parameters.

Quantitative assessment of HRV indicators can serve as a valuable tool for evaluating central nervous system regulation and compiling school health records. Parameters like IN, IVR, VPR, and PAPR can offer insights into children's body regulatory system tension, aiding in assessing students' adaptation to the educational process and guiding educational load planning.

This study aims to investigate HRV parameters in primary school-aged children of different sexes with varying academic performances. By examining how academic success

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correlates with HRV parameters, the research seeks to deepen understanding of the interplay between educational outcomes and physiological regulation, contributing to the development of more comprehensive approaches to student well-being and academic support.

2 Research methodology

Air pollution is comprised of a combination of particulate matter (PM), gases, and gaseous co-pollutants, with particles ranging from nanometers to micrometers in size. Particulate matter can be coarse (PM10), fine (PM2.5), or ultrafine. Gaseous pollutants include nitrogen, sulfur oxides, volatile organic chemicals (VOCs), and secondary pollutants like ozone and various acids.

PM10 pollution primarily originates from industries, mining, and construction, while PM2.5 pollution is mainly caused by combustion of fossil fuels, biomass, or agricultural residue burning. Ultrafine particles, along with VOCs, are often emitted from vehicle exhaust. In winter, smog—a mixture of PM2.5 and fog—becomes prevalent. According to the World Health Organization (WHO), the acceptable daily levels of PM2.5 are 10 μg/m³ for the annual mean and 25 μg/m³ for the 24-hour mean. For PM10, the acceptable levels are 20 μg/m³ for the annual mean and 50 μg/m³ for the 24-hour mean. However, standards are less stringent, with PM2.5 levels set at 40 μg/m³ for the annual mean and 60 μg/m³ for the 24-hour mean, and PM10 levels set at 60 μg/m³ for the annual mean and 100 μg/m³ for the 24-hour mean.

The study respondents were thirty-five full-time female students. Data from the summer season of the year were considered initial. The readings were taken in comfortable conditions once in each season of the year. Considering that in the average month of each season of the year, weather and climatic conditions characteristic of the season are established, the indicators were determined in January, April, June and October.

Cardiovascular system indicators were determined using an OMRON M3 Expert tonometer and an Alton-03 electrocardiograph. The experimental data were statistically processed by the Biostatistics program. Student's t-test was used to compare group indicators.

3 Results and Discussions

This study examines the impact of various environmental factors on Heart Failure (HF) decompensations, as reflected in hospital admissions. To achieve this, a regression model for time series was constructed, and the external attributes with the greatest influence on the number of hospitalizations were tested. In this context, it was concluded that air temperature is the most significant environmental factor, although other attributes, such as precipitation, as well as SO2 and NOX air quality parameters, were also found to be relevant.

In the future, these environmental factors will be integrated into existing predictive models designed to assess the risk of decompensation in ambulatory HF patients. This predictive model forecasts decompensation risk over a seven-day period, utilizing patient monitoring data from preceding days. Incorporating the environmental factors identified in this study is expected to enhance the predictive accuracy of the model.

Furthermore, while the primary objective of the study was to identify the influence of environmental attributes on HF decompensations, there is potential to develop a predictive model for forecasting the number of hospital admissions in the upcoming week. Such a model could be invaluable for physicians in anticipating potential hospital bed shortages.

Initial testing of this model using an ARIMA predictive model yielded a mean error of four admissions per week (based on a weekly hospitalization rate of 28). However, it's important to note that this testing was conducted using the same dataset for both training and testing. Therefore, generalization of these results is contingent upon testing the model with new datasets, making this an area for future investigation.

Meta-analyses were conducted only when two or more eligible studies examined the association between the same pollutant and HF. A random effects model was utilized to estimate the quantitative associations of short-term and long-term exposure to air pollutants with HF risk, accounting for heterogeneity among studies. Heterogeneity was assessed using I2 statistics, with an I2 value ≥75% indicating considerable heterogeneity. Funnel plots were employed to assess study asymmetry. The Egger's regression test was utilized (only when the number of studies was ≥10) to test for publication bias, with a p-value <0.05 indicating significant publication bias. The Trim and Fill method was also employed to further test and adjust for possible publication bias.

Additional stratified analyses for short-term exposure were carried out by geographical location, age, outcome, study design, covered area, methods of exposure assessment, and length of exposure window (each subgroup included at least two studies) to determine whether a potentially susceptible population may exist. For long-term exposure, stratified analyses were conducted according to covered area, exposure window, exposure stage, and geographical location. Due to the limited studies included for long-term exposure to SO2 and CO, stratified analysis was not performed for these exposures. Meta-regressions were conducted for air pollutants with at least 10 studies included to investigate the source of heterogeneity, adjusting for several factors such as publication year (continuous), sample size (continuous), population characteristics (general population or CVD patients, age ≥65 years old or all ages), regions (continent, single or multicity), exposure assessment (monitoring or modeled data), exposure window (only applied in long-term exposure; 1 year or >1 year), outcome definition (only applied in short-term exposure; emergency visit, hospitalization, or mortality), and study design (only applied in short-term exposure; time-series, case-crossover, or survival analysis). For each pollutant, the meta-regression model with the best R2 under the premise of convergence was selected as the main model. Sensitivity analysis was conducted to test the robustness of results by excluding studies with maximum or minimum effect size, a special period (i.e., wildfire or storm), small sample size (<10,000 participants), special population (i.e., patients with CVD or HF), and high risk of bias.

This study synthesized additional evidence on the association between exposure to air pollutants and HF. Both short- and long-term exposure to PM2.5, PM10, and NO2 were found to be significantly associated with a higher risk of HF. Notably, only short-term exposure to SO2 and CO showed remarkable associations with HF, while long-term exposure did not. Neither short- nor long-term exposure to O3 was significantly associated with an increased risk of HF.

Building upon the previous study by Shah et al., we included more evidence on short-term exposure from a wider range of low- and middle-income countries (LMICs) and employed different exposure measurements and multiple lags. Consistently, short-term exposure to almost all pollutants, except O3, showed associations with the risk of HF, particularly with a longer lag time. Interestingly, the HF risks associated with all gaseous pollutants were higher in our study compared to those reported in the previous review. For instance, the overall risk of short-term exposure to NO2 was estimated to be 1.038, which is larger than the risk previously reported (RR=1.017). The positive associations were stronger when exposure was considered over the previous 2 days (lag 0–1) rather than on the day of exposure only (lag 0), contrary to the results of the strongest associations at lag 0 in the previous meta-analysis, especially concerning exposure to particulate matter.

Additionally, the short-term studies included in our meta-analysis covered a wider range of concentrations and had larger medians of average concentrations in PM2.5, PM10, SO2, and O3, compared to previous studies.

4 Conclusions

This paper investigates the influence of various environmental factors on episodes of Heart Failure (HF) decompensations, as reflected in hospital admissions. A regression model for time series analysis was developed to identify the external attributes that most significantly impact the frequency of hospitalizations. The study found that air temperature emerged as the primary environmental factor affecting HF decompensations, with precipitation and air quality parameters such as SO2 and NOX also demonstrating relevance.

In future research, these environmental factors will be integrated into existing predictive models aimed at assessing the risk of decompensation in ambulatory HF patients. This predictive model, which predicts decompensation risk within a seven-day timeframe, utilizes patient monitoring data from preceding days. Incorporating the environmental factors identified in this study is expected to enhance the predictive accuracy of the model.

Additionally, while the primary aim of the study was to identify the influence of environmental attributes on HF decompensations, there is potential to develop a predictive model for forecasting the number of hospital admissions in the upcoming week. Such a model could be invaluable for physicians in anticipating potential hospital bed shortages. Initial testing of this model using an ARIMA predictive model yielded a mean error of four admissions per week (based on a weekly hospitalization rate of 28). However, it's important to note that this testing was conducted using the same dataset for both training and testing. Therefore, generalization of these results is contingent upon testing the model with new datasets, making this an area for future investigation.

Nevertheless, the full extent of air pollution's impact on HF hospitalization, incidence, and mortality requires further exploration across various dimensions. Firstly, the distinction between short- and long-term exposures to air pollution is somewhat arbitrary, thus future studies that consider both types of exposure are imperative. Secondly, most studies currently assume a linear relationship between pollution concentration and HF, but the true dose–response relationship between air pollution and HF warrants further investigation. Thirdly, while associations between air pollutants and HF have been estimated, they may be more pronounced in patients with pre-existing HF or other underlying conditions that can compromise heart function. Due to data limitations, accurately estimating the impact of air pollution on patients with different phenotypes or grades of cardiac insufficiency remains challenging. Fourthly, prolonged cumulative exposure to air pollution appears to pose a higher risk of HF compared to myocardial infarction and other cardiovascular diseases. This may be attributed to HF often being the end stage of many heart diseases, particularly coronary artery disease, with existing heart issues such as atrial fibrillation potentially exacerbating HF prognosis. Delving into the underlying causes and potential mechanisms requires further research. Therefore, there is an urgent need for more high-quality studies to elucidate the cardiovascular effects of air pollution comprehensively.

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