Seasonal Influence in Traffic-Related Air Pollutants Concentrations in Urban Parks from Porto Alegre, Brazil

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Abstract

Traffic-related air pollution is an alarming source of pollutants exposure and consequently to the development of several adverse health effects. Otherwise, green spaces are reported to improve health status. Although, in an urban scenario most of these areas are located near air pollutants sources, as vehicle fleet. Thus, the aim of the present study was to determine, during one year, the levels of nitrogen dioxide (NO_2) and ozone (O_3) in the main parks from Porto Alegre—Brazil. This study focused on three urban parks: Germânia, Moinhos de Vento and Marinha do Brasil Park. Nitrogen dioxide and ozone measurements were accessed by passive monitoring in four campaigns including all seasons and performed at distances of 0 m, 15 m, 30 m, 45 m, 60 m and 75 m from the main road at each park. NO_2 and O_3 concentration among the parks was not different ($p > 0.05$), as well as the mean concentration of NO_2 and O_3 of all parks in the six sites did not differ ($p > 0.05$). However, season 1 and 3 showed increased NO_2 and O_3 concentration. Temperature were decreased in season 1 and 3 ($p < 0.05$), while humidity, pressure and insolation showed no difference among seasons ($p > 0.05$). Traffic flow was higher in Moinhos de Vento Park and Marinha do Brasil Park compared to Germânia Park ($p < 0.05$). Overall, the seasonal variation could directly interfere in NO_2 and O_3 concentration in urban parks from Porto Alegre.

Keywords

Air Pollution, Environmental Monitoring, Urban Parks, Seasonal Variation

1. Introduction

Air pollution has become a major risk factor threatening human health. In modern metropolises, the requirement of a huge amount of environmental resources occurs mainly due to the accelerated expansion of the economy and population growing [1] [2]. The exposure to a polluted atmosphere may result in damage to our environment and potential health risk to humans. Reports demonstrated that every year outdoor air pollution is responsible for 4.2 million deaths around the world, while indoor air pollution for 3.8 million deaths [3]. Exposure to air pollutants as nitrogen dioxide (NO_2) and ozone (O_3) has been correlated with increase in mortality and hospital admissions caused by respiratory and cardiovascular diseases. These outcomes have been found both in short and long-term studies [4] [5] [6] [7].

Our society still relies heavily on fossil fuels for various purposes, such as transportation, due to this, traffic-related air pollution is an alarming source of human exposure to air pollutants [2] [8]. Many health studies have connected adverse health effects with spending significant amounts of time near high-traffic roads with elevated air pollution levels [9] [10] [11] [12]. Otherwise, green spaces are reported to improve health status once people use public areas to perform physical activity and have a leisure time, which serves as a key strategy to maintain and improve population health [13]. Although, in an urban scenario, most of these areas are located near air pollutants sources, as vehicle fleet [14]. Some researchers have alert that health risks from exposure to air contaminants may increase during exercise because ambient air pollutants affect health and exercise may amplify the respiratory uptake and deposition of air pollutants in the lungs [15]-[20].

Trees and other vegetation reduce air pollution levels through the interception of airborne particles or through the uptake of gaseous air pollution through leaf stomata on the plant surface [21] [22] [23] [24]. On the other hand, Nowak and colleagues (2010) showed that removed pollution particles can be re-suspended to the atmosphere during turbulent winds, negatively impacting local air. Besides that, high vegetation can reduce mixing and turbulence resulting in increased pollutants concentration levels [25]. This can be explained by the fact that trees and other types of vegetation reduce the ventilation that is responsible for diluting the traffic emitted pollutants. Several studies demonstrated that green spaces located in urban street canyons can obstruct the wind flow thereby reducing the ventilation leading to higher pollutant concentrations [26] [27].

In view of the indisputable health benefits of exercising and having leisure times together with the little amount of knowledge about the levels of air pollution at public urban parks it is important to know the concentration of pollutants gases and understand the factors that affects it. So, the aim of the present study was to determine, during one year, the levels of NO_2 and O_3 in the main parks from Porto Alegre—Brazil.

2. Methods

2.1. Study Area

The study was conducted in the city of Porto Alegre (30˚01'59"S, 51˚13'47"W), which is the principal city from the state of Rio Grande do Sul, located in the Southern Brazil. This city has approximately 1.409 million inhabitants (2.83 people per km^2) and the climate is considered humid-subtropical, with above-average precipitation throughout the year.

This study focused on three representative urban parks that were chosen for field experiments: Germânia Park, situated at Túlio de Rose avenue (30.0256˚S, 51.1588˚W), comprising a green area of 15.11 hectares; Moinhos de Vento Park, situated at Goethe avenue (30.0271˚S, 51.2007˚W), comprising a green area of 11.5 hectares and Marinha do Brasil Park, situated at Borges de Medeiros avenue (30.0493˚S, 51.2302˚W), comprising a green area of 11 hectares (**Figure 1**). To avoid differences due to geographical distribution of air pollutants, NO_2 and O_3 sampling was performed at distances of 0 m, 15 m, 30 m, 45 m, 60 m and 75 m from the main road at each park (sites 1-6). The filters were installed in the corner of the parks, where was the intersection of the highways and then installed from the corner gradually to the center in a straight line within 15 m of distance from each other.

2.2. Air Pollutants and Meteorological Parameters

The four sampling campaigns (September/2017 = season 1; January/2018 = season 2; June/2018 = season 3; September/2018 = season 4) were chosen to examine pollutant patterns over more than one season, to ensure that our findings were robust over time. In each campaign vehicular traffic was recorded and blind analyses of vehicular flow was performed by two observers. Climatic variables (air temperature, relative humidity, pressure, wind direction and insolation) were obtained from INMET (National Institute of Meteorology) recorded at José Luiz Carneiro Cruz public square (Porto Alegre, Brazil).

In this study, cellulose filters (37 mm, Energética, Rio de Janeiro, Brazil) were used as a diffusive surface into a sampler which was placed in trees at a height of 2 meters, as illustrated in **Figure 2**. NO_2 measurements followed Lodge Jr (1988)

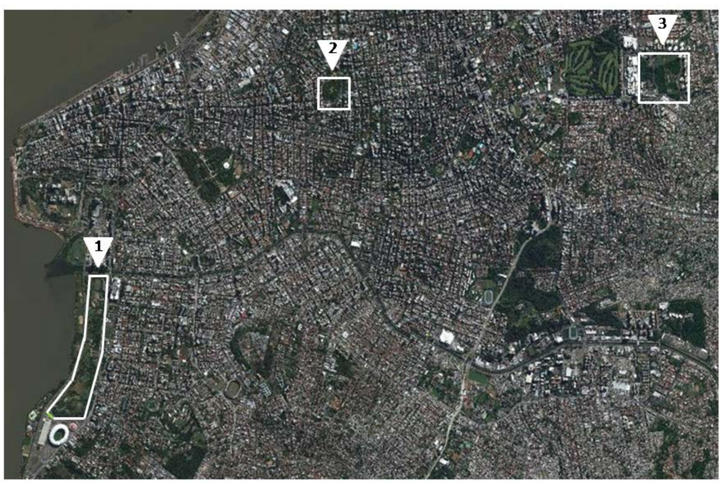

Figure 1. Spatial distribution of investigated parks. 1) Marinha do Brasil Park; 2) Moinhos de Vento Park; and 3) Germânia Park.

Figure 2. Filters of NO_2 and O_3 installed in park trees for monitoring sampling.

protocol [28]. Cellulose filters were impregnated with triethanolamine (200 μL), as a liquid absorber solution, and then dried at 37˚C for 24 h. After this period, filters were placed in open plastic tubes and placed at monitoring areas for 7 days. Blank filters were acquired using filters in the same conditions as the exposed but without atmosphere contact, inside a closed ziplock bag. The solution obtained was analyzed spectrophotometrically at 550 nm (Perkin-Elmer Lambda 35, São Paulo, Brazil).

O_3 measurements followed Scheeren and Adema (1996) protocol [29]. Cellulose filters were impregnated with indigo carmine as a liquid absorber solution in a dark ambient to prevent the degradation light effect. After impregnating the filters with 200 μL of absorber solution, they were left to dry for 4 min in room temperature before a second impregnating procedure (200 μL). After this period, filters were placed in dark open plastic tubes and placed at monitoring areas for 24 h. Blank filters were acquired using filters in the same conditions as the exposed but with no contact with direct sunlight and atmosphere (inside an aluminum foil ziplock bag) contact. The solution obtained was analyzed spectrophotometrically at 610 nm (Perkin-Elmer Lambda 35, São Paulo, Brazil).

2.3. Statistical Analysis

Statistical analysis was carried out using SigmaPlot version 12.0 for Windows (Systat Software, Inc.) and GraphPad Prism version 6.0 for Windows (Prism 6;

GraphPad Software, Inc.). Study variables were tested for normality using Shapiro-Wilk or Kolmogorov–Smirnov test. To analyze parks and sites variables we used one-way ANOVA, followed by Tukey's post hoc test. The interaction between parks and seasons were obtained by two-way ANOVA, followed by Tukey's post hoc test. Values were reported as mean ± standard deviation. A $p < 0.05$ was considered statistically significant.

3. Results

In the present study, NO_2 concentration among the parks was not different ($p = 0.447$) (**Figure 3(a)**). The NO_2 concentration average of all parks in the six sites did not differ among them ($p = 0.993$) (**Figure 3(b)**). In season 1, NO_2 concentration were increased when compared to season 2 ($p = 0.007$). Also, it was observed an increase of NO_2 concentration in season 3 when compared to seasons 1 ($p = 0.048$), 2 ($p < 0.001$), and 4 ($p < 0.001$) (**Figure 3(c)**). While, when the interaction of seasons with the parks was compared, it was observed an increase of NO_2 concentration in season 1 compared to season 2 ($p = 0.005$) and in season 3 compared to seasons 1 ($p = 0.0449$), 2 ($p < 0.001$), and 4 ($p < 0.001$) in all parks (**Figure 3(d)**).

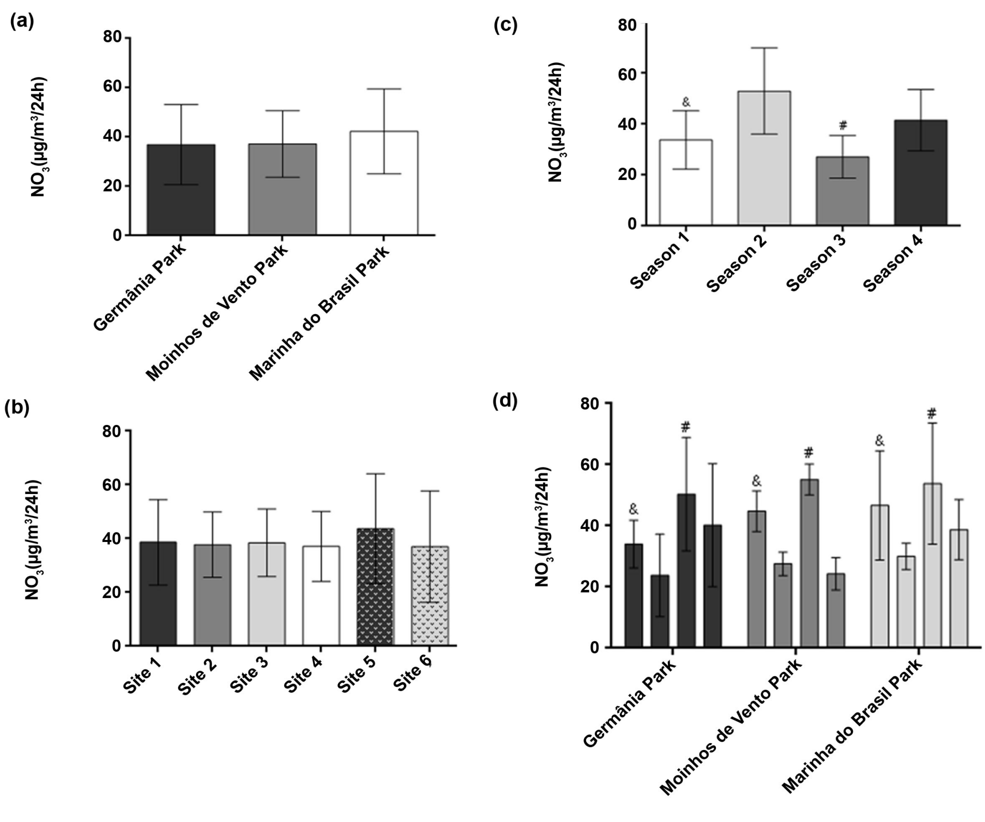

Figure 3. NO_2 concentrations in monitoring parks; (a) NO_2 concentration in all parks during the year; (b) NO_2 concentration in the six sites of the parks; (c) NO_2 concentration in the four seasons; (d) NO_2 concentration of four seasons in parks. Values presented as mean ± SD. Statistical analysis: one-way ANOVA followed by Tuckey's *post hoc* test for **Figure 3(a)** and **Figure 3(b)**; two-way repeated measures ANOVA followed by Tuckey's *post hoc* test for **Figure 3(c)**. Symbols represent comparison among groups based on the *post hoc* analysis: &—$p < 0.05$ vs. 2; #—$p < 0.05$ vs. 1, 2 and 4. GraphPad Prism (Prism 6; GraphPad Software, Inc.) were used to graphs elaboration.

Regarding O_3 concentrations, a difference among the parks was not observed ($p = 0.670$) (Figure 4(a)). Also, the O_3 concentrations among the six sites of the parks were not different ($p = 0.898$) (Figure 4(b)). O_3 concentrations in seasons demonstrated an increase in season 1 and 3 compared to season 2 ($p < 0.001$) and 4 ($p < 0.001$), and augment in season 2 when compared to season 4 ($p = 0.025$) (Figure 4(c)). In addition, the O_3 concentration in Germânia Park was increased in seasons 1 and 3 when compared to seasons 2 ($p < 0.001$) and 4 ($p < 0.001$). In Moinhos de Vento Park, the O_3 concentration was increased in season 1, 2 and 3 compared to season 4 ($p < 0.001$). In Marinha do Brasil Park, the O_3 concentration was increased in season 1 when compared to season 2 ($p = 0.030$) and 4 ($p < 0.001$), and season 3 compared to season 1 ($p < 0.001$), 2 ($p < 0.001$) and 4 ($p < 0.001$). Marinha do Brasil Park showed increased O_3 concentration in season 3 when compared to all seasons in Germânia ($p < 0.001$) and Moinhos de Vento ($p < 0.001$) parks (Figure 4(d)).

The meteorological measures of the seasons showed that season 1 and 3 had decrease temperatures compared to seasons 2 and 4 ($p < 0.05$). Humidity, pressure and insolation showed no difference among seasons (Figure 5). When assessed

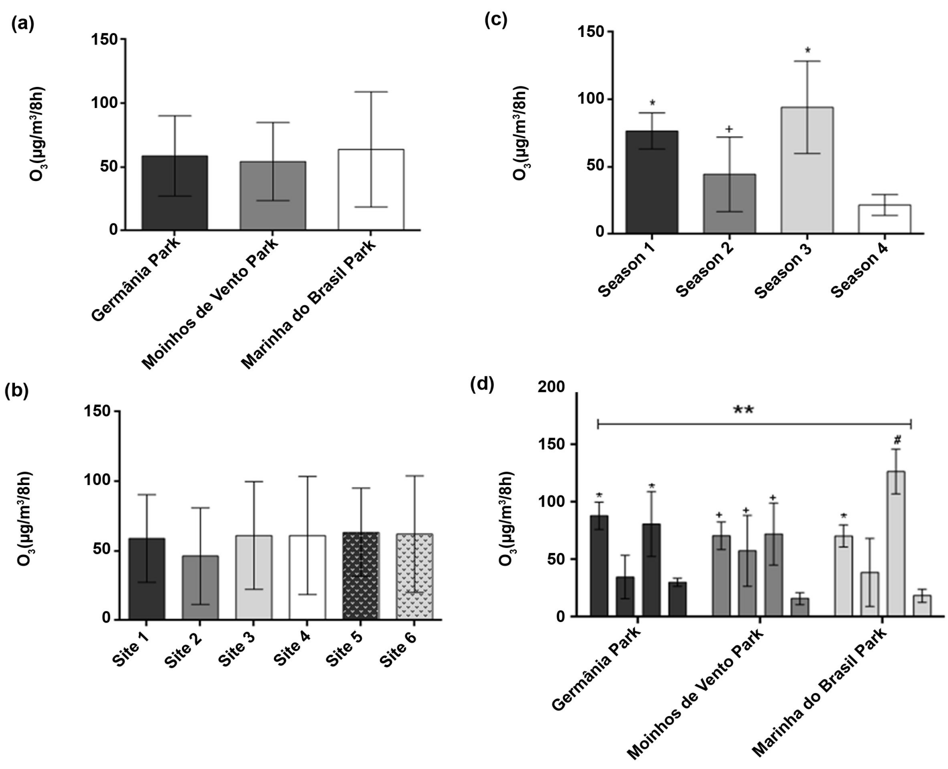

Figure 4. O_3 concentrations in monitoring parks; (a) O_3 concentration in all parks during the year; (b) O_3 concentration in the six sites of the parks; (c) O_3 concentration in the four seasons; (d) O_3 concentration of four seasons in parks. Values presented as mean ± SD. Statistical analysis: one-way ANOVA followed by Tuckey's *post hoc test* for Figure 4(a) and Figure 4(b); two-way repeated measures ANOVA followed by Tuckey's *post hoc* test for Figure 4(c). Symbols represent comparison among groups based on the *post hoc* analysis: *—$p < 0.05$ vs. 2 and 4; +—$p < 0.05$ vs. 4; #—$p < 0.05$ vs. 1, 2 and 4; **—$p < 0.05$, season 3 of Marinha do Brasil Park vs. all seasons of parks. GraphPad Prism (Prism 6; GraphPad Software, Inc.) were used to graphs elaboration.

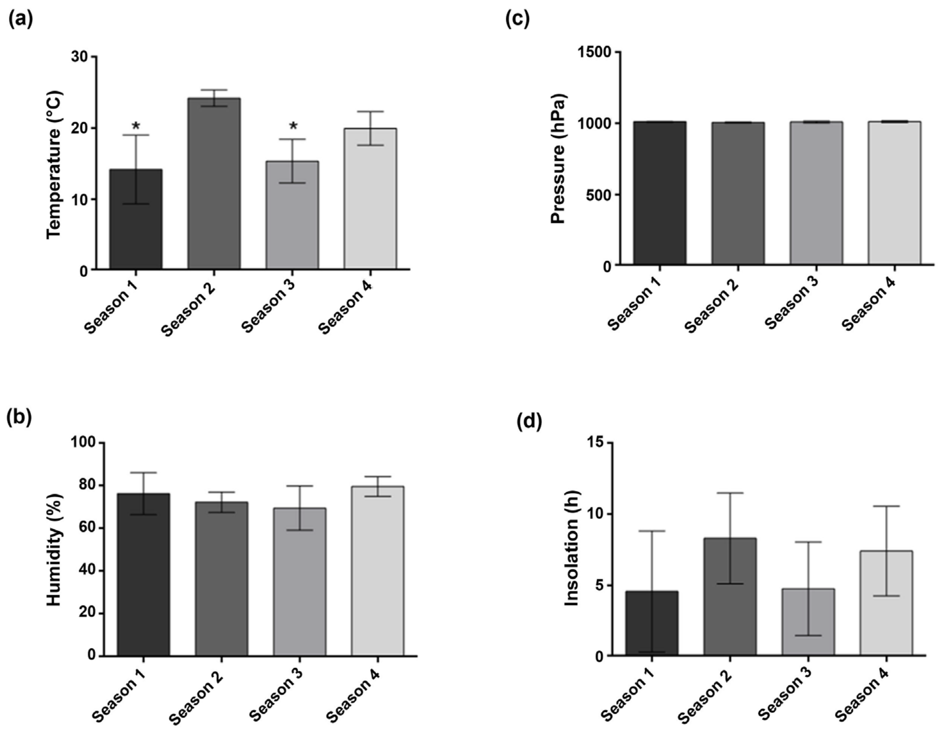

Figure 5. Meteorological measures of monitoring seasons. (a) Temperature; (b) Humidity; (c) Pressure; (d) Insolation. Values presented as mean ± SD. Statistical analysis: one-way ANOVA followed by Tuckey's *post hoc* test. Symbols represent comparison among groups based on the *post hoc* analysis: *—$p < 0.05$ vs. 2 and 4. GraphPad Prism (Prism 6; GraphPad Software, Inc.) were used to graphs elaboration.

the traffic flow in streets surrounding the parks, Moinhos de Vento Park showed a higher traffic flow compared to Germânia Park and Marinha Park ($p < 0.05$) being the number of cars/minute of 108 and 36, respectively. Also, Marinha Park demonstrated increased traffic flow compared to Germânia Park ($p < 0.05$), with 69 cars/minute.

4. Discussion

The results of this study showed a seasonal variation of pollutants concentrations among urban parks, demonstrating that mainly season 1 and 3 had higher concentrations of NO_2 and O_3. The unique meteorological measure that may potentially interfere in this variation is temperature. So, in the seasons with lower temperature, an increase on traffic–related air pollution concentration was detected. Furthermore, there was no difference among parks concentration of NO_2 and O_3, neither a gradient of the pollution dispersion was observed in this study.

The absence of difference in NO_2 and O_3 concentration among parks during the year indicates that studied parks demonstrated similar levels of air pollutants. However, the seasonal variation observed in our study influence the concentration of pollutants concentrations, given that an increase in NO_2 and O_3 concentrations was observed in the coldest seasons (1 and 3). In contribution to our result, cold seasons are associated with high pollution episodes, being the highest levels of pollutants occurring in winter [30] [31] [32] [33]. During low temperature and winter days, thermal inversion is commonly observed, and, in this period, the concentration of pollutants tends to be higher, leading to a poor air quality environment [34]. Also, parks could intensify low temperature and contribute to pollution concentration due to the shading and cooling effect caused by trees that act as barrier of pollutants [35] [36].

Season 3 of Marinha do Brasil Park had increased levels of O_3 when compared to all seasons in other parks. Despite vegetation of urban parks be recognized to mitigate the pollutants concentration in green areas, some characteristics must be taken into account, as structural aspects: vegetation structure, composition and management, considering the components in terms of trees, shrubs, herbaceous vegetation and lawns [21] [36]. So, the difference observed in our study may be a result from structural characteristics of Marinha do Brasil Park.

The formation of a pollution gradient depends on distance, barriers and type of pollutant, and a decay of half of the maximum concentration pollutant could occurred at a distance around 150 m from the source [37] [38] [39]. In our study, we evaluated the concentration of NO_2 and O_3 in a gradient way with sites 15 m from each other, starting in the board of the park through the center, summering 75 m and no difference was observed among the sites. In a study of Chang and colleagues (2015), a framework to inform exposure estimates for traffic–related air pollutants with a high spatial resolution was developed and it was demonstrating that concentrations of traffic-related air pollutants drop by over 40% within 200 m away from the roadway [40]. So, the distance analyzed in our study was not enough to cause a decrease in NO_2 and O_3 concentrations. Overall, urban parks from Porto Alegre are not sufficiently extensive to mitigate the pollution concentration by dispersion.

Regarding the traffic flow in streets surrounding the parks, although Moinhos de Vento Park had increased traffic compared to other parks and Germânia the lower traffic, these results did not interfere in pollution concentration detected, once it was not observed difference among parks when all seasons were included. However, when each season was analyzed, O_3 concentrations in Moinhos de Ventos Park was higher in season 1, 2 and 3 compared to 4, while in other parks only season 1 and 3 was increased. So, this result could derivates of the high traffic flow in streets close to Moinhos de Vento Park, once road traffic is the main air pollutant emitter in urban areas [37] [41].

Our study had a limitation that must be considered. We did not measure additional pollutants released from vehicular emissions, such as MP2.5 and SO_2. The levels of these pollutants associated with NO_2 and O_3 concentration could provide a more complex panorama to our study and a better understanding of our results.

5. Conclusion

Thus far, the seasonal variation could directly interfere in NO_2 and O_3 concentration in urban parks from Porto Alegre. It indicates that cold seasons contribute to the deterioration of air quality. The sites of the parks seem not to interfere in the local air quality, since a gradient of pollutants concentration was not observed.

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Authors' Contributions

Bruna Marmett and Roseana Böek Carvalho are both first authors of this study and had equal substantial contributions to conception, design, acquisition, analysis and interpretation of data. All authors have involvement in drafting the manuscript and revising it critically for important intellectual content and have approved the final version of the manuscript to be published.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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