The Short-Term Effect of Nitrogen Dioxide on Cardiovascular Mortality is Modified by Season and Temperature in Shenzhen, China

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Background

Given the unstable climate change, interest has grown recently in whether pollutants' effects on mortality are modified by temperature, because climate change may cause changes in air quality and eventually alter the health effects of air pollution.

Objective

As few research have considered the modifying effect of temperature on NO_2, the interaction between the temperature and NO_2 remains to be unclear. In this study, we sought to examine the interaction between NO_2 and temperature regarding the air pollution–mortality relationship.

Methods

Data

The data collected included daily cause-specific deaths, weather conditions, and air pollutant concentrations from 2013 to 2017 in Shenzhen, China.

Statistical Methods

1. Distributed Lag Linear Models (DLMs) was used to allow cumulative lag effects.
2. Generalized additive models (GAMs) combined with stratification parametric model was used to examine the interaction between NO_2 air pollutants and temperature for cardiovascular mortality at the effect of cumulative lag effect.
3. GAMs combined with joint air pollution–temperature response surfaces was used to show the three dimensional surfaces.

Results

For full year, percentage increase in death of NO_2 concentration for mortality exceeded zero for single lag0 and lag1 days for all people. In the cold season, percentage increase was highest at single lag0, lag1 and lag2 days. For the warm season, percentage increase was no significant for all groups (Figure 1).

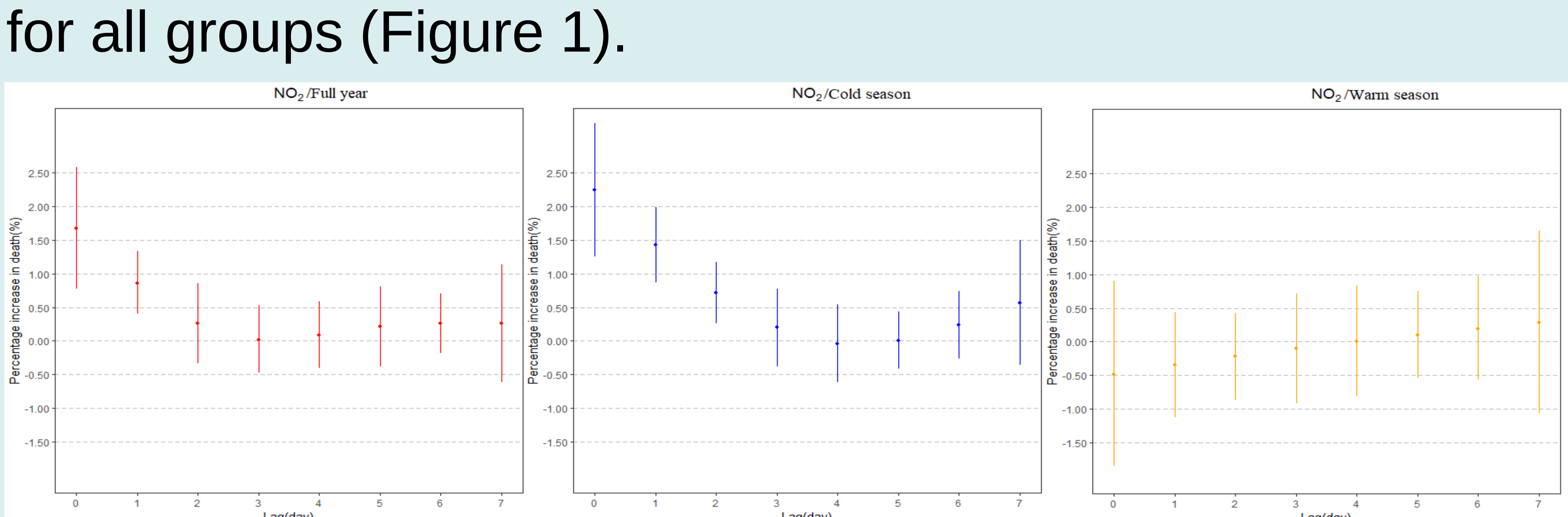

Figure 1. Lag-specific effects of each 10μg/m³ increment in NO_2 concentration in air pollutants on daily death counts for cardiovascular death using DLM models

In cold season, the percentage increase in death for each 10μg/m³ increment in NO_2 concentration on cardiovascular mortality was associated with a 4.45% (95% *CI*: 2.71-6.21%) and 4.87% (95% *CI*: 2.73-7.05%) increase of mortality for lag0-2 and lag0-6, respectively. There was no significant effects observed in the warm season. (Table 1).

Table 1. Percent increase (95% *CI*) of cardiovascular mortality for each 10μg/m³ increment in NO_2 concentration, during different lag days in Shenzhen, 2013-2017.

	Effect	Percentage increase in death (95% *CI*)		
		Lag0-2	Lag0-4	Lag0-6
All [a]	Full year	2.81(1.46, 4.19)*	2.93 (1.33, 4.55)*	3.41 (1.55, 5.30)*
	Cold season	4.45 (2.71, 6.21)†	4.61 (2.61, 6.66)†	4.87 (2.73, 7.05)†
	Warm season	-1.06 (-3.41, 1.36)	-1.15 (-3.88, 1.66)	-0.85 (-3.82, 2.21)
Females	Full year	3.35 (1.23, 5.51)*	2.88 (0.41, 5.41)*	1.98 (-0.87, 4.91)
	Cold season	4.76 (2.13, 7.46)	4.75 (1.71, 7.87)	4.11 (0.91, 7.42)
	Warm season	1.49 (-2.35, 5.48)	1.11 (-3.35, 5.78)	-0.22 (-5.02, 4.82)
Males	Full year	2.49 (0.77, 4.23)*	2.97 (0.94, 5.04)*	4.35 (1.98, 6.78)*
	Cold season	4.24 (2.06, 6.47)†	4.53 (2.01, 7.10)†	5.36 (2.67, 8.12)†
	Warm season	-2.62 (-5.57, 0.42)	-2.55 (-5.96, 0.99)	-1.29 (-5.02, 2.59)
<65 years	Full year	2.94 (0.75, 5.18)*	3.84 (1.25, 6.50)*	4.76 (1.73, 7.89)*
	Cold season	2.75 (-0.05, 5.63)	3.31 (0.08, 6.64)	4.45 (0.99, 8.03)
	Warm season	0.10 (-3.60, 3.94)	0.63 (-3.68, 5.12)	2.47 (-2.27, 7.44)
≥65 years	Full year	2.77 (1.11, 4.46)*	2.47 (0.52, 4.45)*	2.72 (0.46, 5.03)*
	Cold season	5.33 (3.25, 7.45)†	5.30 (2.90, 7.75)†	5.07 (2.53, 7.67)†
	Warm season	-1.73 (-4.75, 1.39)	-2.20 (-5.69, 1.42)	-2.81 (-6.57, 1.11)

[a] "All" meant daily death count, not stratified by sex and age.
* Statistically positive significant results at the 5% level ($P < 0.05$)
† Z test for the difference between the two relative risks of subgroup analysis results at the 5% level ($P < 0.05$)

Daily average temperature and NO_2 concentration had interactive negative effects, for each 10μg/m³ increment in NO_2 concentration, cardiovascular deaths increased by 3.51% (95% *CI*: 2.04-5.01%) on low-temperature level days at lag0-2 day. In addition, elderly (age ≥65 years) and males people were more vulnerable to this interaction (Table 2).

Table 2. Percent increase (95% *CI*) of cardiovascular mortality for each 10μg/m³ increment in NO_2 concentration at different temperature levels, during different lag days in Shenzhen, China, 2013–2017.

	Temperature levels [b]	Percentage increase in death (95% *CI*)		
		Lag0-2	Lag0-4	Lag0-6
All [a]	Low	3.51 (2.04, 5.01)†	3.43 (1.71, 5.18)†	3.47 (1.53, 5.45)
	High	-0.06 (-2.54, 2.49)	-0.17 (-3.06, 2.80)	0.42 (-2.77, 3.71)
Females	Low	3.76 (1.47, 6.11)	3.28 (0.62, 6.01)	2.55 (-0.44 5.63)
	High	0.99 (-2.94, 5.09)	-0.82 (-5.33, 3.91)	-1.76 (-6.68 3.43)
Males	Low	3.38 (1.50, 5.29)†	3.56 (1.37, 5.80)	4.11 (1.64 6.65)
	High	-0.73 (-3.83, 2.47)	0.19 (-3.43, 3.95)	1.73 (-2.30 5.92)
<65 years	Low	2.49 (0.08, 4.96)	3.34 (0.53, 6.22)	3.53 (0.37 6.79)
	High	1.24 (-2.69, 5.33)	2.45 (-2.15, 7.25)	3.90 (-1.20 9.27)
≥65 years	Low	4.08 (2.28, 5.91)†	3.51 (1.42, 5.65)†	3.48 (1.12, 5.90)†
	High	-0.82 (-3.88, 2.34)	-1.69 (-5.23, 1.98)	-1.60 (-5.49, 2.45)

[a] "All" meant daily death count, not stratified by sex and age.
[b] The 50th percentiles of daily mean temperature were used as temperature cut-offs.
† Z test for the difference between the two relative risks of subgroup analysis results at the 5% level ($P < 0.05$)

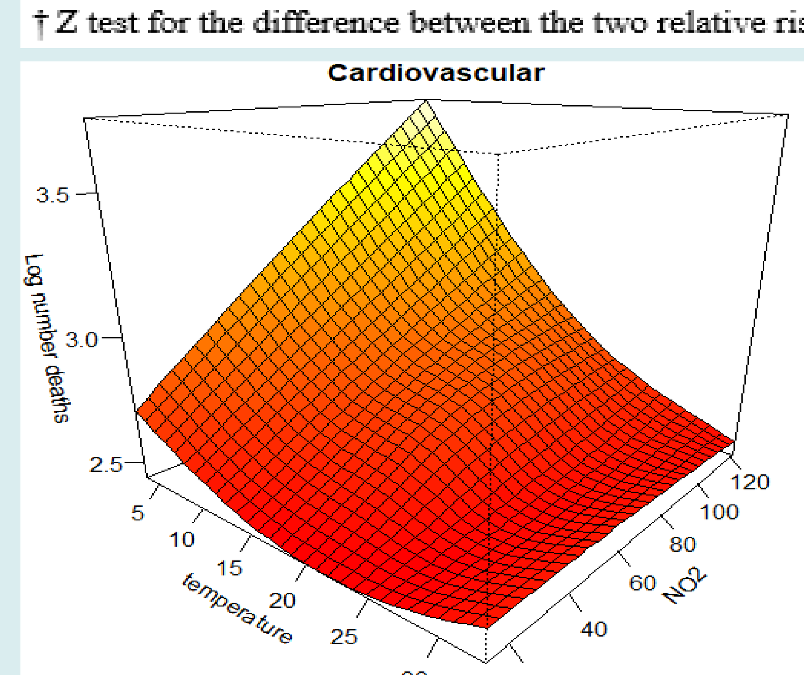

Figure 2. Bivariate response surface of temperature and NO_2 on health outcomes.

Potential interactive effects of temperature on NO_2 regarding cardiovascular outcomes show that low temperature enhance the effects of NO_2 on mortality risk (Figure 2).

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Conclusion

Season and temperature strongly modified the adverse effect of NO_2, our study showed that cold season and on days with low temperature could significantly enhance the effect of NO_2 on cardiovascular mortality. Which implicated that an increase in the number of low temperature days by global climate change may alter the health effects of air pollution.