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An Australian national panel study of diurnal temperature range and children's respiratory health

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ABSTRACT

Background: It is still uncertain whether diurnal temperature range (DTR) affects children's respiratory function.

Objective: To examine the effects of DTR on lung function and respiratory symptoms for school children with asthma in Australia.

Methods: A panel of 270 children (ages 7-12 years) with asthma living in 6 Australian cities was recruited. They were asked to perform 3 successive forced expiratory maneuvers using a portable electronic peak flow meter twice daily for 4 weeks. The highest values for peak expiratory flow (PEF) were stored for each session. At the same time, they were asked to record their respiratory symptoms (eg, cough and/or phlegm and wheeze and/or chest tightness) every day in the morning (for nighttime symptoms) and evening (for daytime symptoms). Daily data on different metrics of ambient temperature and air pollution were obtained from fixed monitors nearby. Relative humidity data were downloaded from the Weather Underground website. Mixed models, adjusting for children's individual characteristics and air pollution, were used to examine the effects of DTR on PEF and respiratory symptoms.

Results: DTR had linear effects on PEF and respiratory symptoms. An increase in DTR induced a reduction in PEF and increased the occurrence of respiratory symptoms. In general, the effects lasted for 3 days (lag, 0-2 days). The effects occurred for both boys and girls.

Conclusion: Our findings provide evidence that DTR had significant effects on lung function and respiratory symptoms for children with asthma. These results indicate that it is important and necessary to protect children with asthma from the effect of unstable weather.

Introduction

Recently, a number of studies have examined the association between ambient temperature and disease.[1,2] However, less evidence is available on the effects of diurnal temperature range (DTR) on health. DTR, calculated as the difference between maximum and minimum temperatures within 1 day, is considered an important index of weather change (or weather variability) because it provides more information than the daily mean temperature alone.[3] A small numbers of studies have reported that an increase in DTR adversely affects deaths and hospital admissions.[4–6] However, no previous study has examined the effects of DTR on lung function and respiratory symptoms. Knowledge of this relationship would lead to greater understanding of the effects of short-term temperature changes on respiratory health.

Epidemiologic studies have focused on the health effects of ambient temperature on potentially sensitive population subgroups, such as children, to ensure protection of these susceptible population groups.[7,8] Potential determinants of children's susceptibility include the continuing process of lung growth and development, immature host defenses, high rates of infection with respiratory pathogens, and activity patterns that increase exposure to ambient environment.[9] The prevalence of asthma in Australia is one of the highest in the world, affecting 10% of Australians.[10] It is the leading cause of burden of disease in children aged 0 to 14 years

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in Australia, accounting for 17.9% of the total burden in boys and 18.6% in girls.[11] However, few studies have examined the effects of temperature change on lung function and respiratory symptoms for children with asthma in Australia.

The aim of this article is to examine the short-term effects of DTR on lung function and respiratory symptoms in children with asthma. We used data from an Australia-wide panel study conducted in children. We examined the overall associations and the associations stratified by sex using mixed models, which allow for random effects for individuals. A better understanding of the adverse effects of DTR on lung function and respiratory symptoms among children with asthma will provide important information for developing public health plans and risk assessments in the ambient environment.

Methods

The Australian Child Health and Air Pollution Study is a cross-sectional study that examined both the cumulative and short-term effects of environmental factors (in particular, ambient air pollution, temperature, and relative humidity) on respiratory health in a representative sample of children aged 7 to 12 years living in urban areas of Australia. This study was conducted in 6 major Australian cities: Sydney, Melbourne, Brisbane, Adelaide, Perth, and Canberra. There were at least 2 air monitoring stations per city. All monitoring stations had a 5-year history of monitoring. The study period for each location is described in eTable 1. A panel of children with asthma or asthmalike symptoms was selected from the full Australian Child Health and Air Pollution Study population and formed the basis of the analyses.

Study Ethics

The study protocol was approved by the Departments of Education of the Universities of Queensland and Sydney in the Australian Capital Territory, New South Wales, Queensland, South Australia, Victoria and Western Australia. Ethics approval was also obtained from the Catholic Education Office of Victoria to perform the study at selected Victorian Catholic primary schools. All study participants and their parents or guardians gave written informed consent before participation in the study.

Study Participants

We sampled primary schools that were within 3 km of air monitoring stations. In those schools that met the eligibility criteria and agreed to participate, we distributed an information statement, consent form, and questionnaire to children in all or some classes in school years 3 to 5. This cross-sectional study was conducted during 2007-2008. The questionnaire was completed by a parent and asked questions about respiratory symptoms and illnesses and relevant environmental exposures. Children with physician-diagnosed asthma and symptoms of asthma within the preceding year and who were living within a 3-km radius of the corresponding air monitoring station were invited to take part in the panel study. The panel study was conducted in Melbourne, Brisbane, Adelaide, Perth, and Canberra during 2007 and in Sydney during 2008.

Lung Function Measurement and Respiratory Symptoms Diary

We provided each participant with an electronic peak flow meter (Mini Wright Digital; Clement Clarke, Essex, United Kingdom). They were taught how to use the electronic peak flow meter by trained investigators and asked to perform 3 successive forced expiratory maneuvers before taking any inhaled medication, twice daily for 4 weeks. The highest peak expiratory flow (PEF) from these 3 successive measurements were automatically stored in the device with a date and time stamp.

Children completed a diary for respiratory symptoms and medication use under their parents' instruction every morning (for nighttime symptoms) and evening (for daytime symptoms) for 4 weeks. Respiratory symptoms included cough and/or phlegm and wheeze and/or chest tightness. Symptoms during the night were recorded in the morning, whereas those that occurred during the daytime were recorded in the evening. At the same time, patients were asked to record the use of any bronchodilator (reliever) and preventer or controller medications.

Data on Meteorologic Factors and Air Pollution

Daily data on ambient temperature and air pollution during the study period were obtained from each selected air monitoring station. The measurements of interest for this study included daily mean, maximum, and minimum temperatures and mean ozone concentration during the previous 8 hours for each hour of the day (8-hour rolling mean ozone concentration). We calculated daytime DTR as the difference between the current day's maximum and minimum temperatures and nighttime DTR as the difference between the previous day's maximum temperature and the current day's minimum temperature.

Because data on relative humidity were not available at the monitoring stations, we collected daily mean relative humidity from the Weather Underground website (http://www.wunderground.com/) for each city. We assumed that there were small differences in the spatial distribution of relative humidity within cities. We compared the effect estimates and model fit for models with and without relative humidity.

Statistical Analyses

Generalized additive mixed models (GAMMs) were used to examine the effects of DTR on PEF and respiratory symptoms. We used a gaussian function for modeling PEF, which was normally distributed, and a logistic regression model for symptoms, which was binary. The GAMM allows flexible functional dependence of an outcome variable on covariates by using nonparametric and parametric regression.[12,13] This mixed model is particularly useful in studies where repeated measurements are made on the same subjects (eg, panel study).

To examine whether the effects of DTR on lung function and respiratory symptoms were linear, a natural cubic spline with 3 *df* for DTR was used. Preliminary results revealed that the associations between DTR and children's lung function and respiratory symptoms were linear (Fig 1 and eFig 1) and that the linear model produced the lowest values for Akaike information criterion (AIC) and Bayesian information criterion (BIC) (eTables 2 and 3). Therefore, a linear function was used in the final analyses.

DTR was included in all models as the main fixed effect. Lung function is strongly related to height, is also related to sex and age, and may be related to weight. Respiratory symptoms also vary with sex and age. Therefore, we adjusted for these factors by including them as fixed effects in all the models. Participant identification number was included as a random effect; thus, it had the effect of also adjusting for season and location because each child was uniquely associated with one season and one location.

After establishing the basic model as described above, we introduced daily mean temperature, 8-hour rolling mean ozone concentration, relative humidity, and medication use into the regression model, step by step. By comparing the AIC and BIC values for all models, the model that gave the lowest AIC and BIC values was selected as the final model. We also used the final model to assess the effects of DTR on children's lung function and respiratory symptoms separately for boys and girls.

Because previous studies have reported that effects of ambient temperature appeared not only on the same day but also on subsequent days,[2,14] we examine the lagged effects of DTR on children's