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NO_2 Background Levels at the Address of Residence are More Strongly Associated with Respiratory Symptoms than Exposure Estimates Reflecting Traffic Counts

Die NO_2 Hintergrund-Exposition an der Wohnadresse ist stärker mit Atemwegssymptomen assoziiert als mit Expositionsschätzungen, die aus Informationen über den Verkehr gewonnen wurden

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Exposure to air pollution has been estimated by various methods in epidemiological studies. Data from monitoring stations distant from big roads reflect mainly background immissions whereas self-reports and traffic counts represent rather direct exposure to traffic related pollutants. No study has yet tried to disentangle the associations of these two exposure components with respiratory health. We compared the associations of background exposure to NO_2 and NO_2 exposure estimated by a traffic related model with the respiratory health of 5421 school children (5-7 and 9-11 years old) who were examined as part of the International Study of Asthma and Allergies in Childhood (ISAAC) Phase II. Background NO_2 levels were more strongly associated with cough in the morning than estimates derived from information on local traffic. This result indicates that traffic-related estimates may induce exposure misclassification if they do not take time-activity-patterns into account.
Keywords: respiratory symptoms, exposure estimate, NO_2 background exposure, traffic exposure

Die individuelle Luftschadstoff-Exposition ist in epidemiologischen Studien mit unterschiedlichen Methoden geschätzt worden. Daten von Monitoren in größerem Abstand von großen Straßen geben im wesentlichen Hintergrundimmissionen wieder während Fragebogenangaben und Verkehrszählungen im wesentlichen direkte Exposition mit verkehrsbezogenen Schadstoffen repräsentieren. Keine Studie hat bislang differenziert untersucht, ob diese beiden Expositions-Komponenten unterschiedlich mit Atemwegsgesundheit assoziiert sind. Wir verglichen die Assoziationen von a) individueller Hintergrundexposition mit NO_2 und b) NO_2 Exposition, die durch ein Verkehrs-bezogenes Modell geschätzt wurde, mit der Atemwegsgesundheit von 5421 Schulkindern (5-7 und 9-11 Jahre alt. Die Kinder wurden im Rahmen der Internationalen Studie zu Asthma und Allergien im Kindesalter (ISAAC) Phase II untersucht. Hintergrundexposition mit NO_2 war stärker mit morgendlichem Husten assoziiert als Expositionsschätzungen, die aus Informationen über den Verkehr an der Wohnadresse abgeleitet worden waren. Dieses Ergebnis könnte damit erklärt werden, dass Verkehrs-bezogene Expositionsschätzungen ein Missklassifikation einschließen, wenn sie die täglichen Aktivitätsmuster von Kindern nicht berücksichtigen.
Stichworte: Atemwegssymptome, Expositionsschätzung, NO_2-Hintergrundbelastung, Verkehrsexposition

Introduction

Exposure to traffic related air pollutants has been determined by various methods in epidemiological studies. Some studies used questionnaire-based self-reports (Duhme et al 1996; Ciccone et al 1998), others traffic counts (Wjst et al 1993; Oosterlee et al 1996; English et al 1999; Wyler et al 2000), and again others measurements of traffic related pollutants at monitoring stations in the area of residence (Dockery et al 1989; Studnicka et al 1997; Braun-Fahrländer et al 1997; Hirsch/Weiland/Mutius et al 1999; Brunekreef et al 1997). Personal exposure monitoring has only been performed in smaller studies (Braun-Fahrländer et al 1992; Krämer et al 2000) and the feasibility of such personal measurements is limited for economic and methodological reasons.

However, no study has compared which of the different indirect methods optimally represents true individual exposure and the biologically effective pollutant dose. Self-reports and traffic counts represent mainly pollutant concentrations at the roadside (Hirsch/Kuhlisch/Olunczek 1999). These concentrations decrease rapidly within 30 – 50 m distance (Briggs et al 1997; Monn et al 1997). Children attend these areas only for a minor part of the day (Özkaynak 1999; Spier et al 1992). In contrast, routine measurements at monitoring stations in large cities are mainly determined by the background concentration of air pollutants. These measurements do not reflect individual exposure from smaller sources. No epidemiological study has yet tried to disentangle the associations of these two exposure components with respiratory health.

The aim of this study was to investigate whether additional information on local traffic exposure changes the association of background pollution exposure with respiratory health in children from a large city. At first, we assessed the association of measured NO_2 background exposure with respiratory symptoms and lung function values. In a second step we re-evaluated these associations using an exposure model including information on traffic counts in the street of residence.

Methods

Study population

The respiratory health of 5421 children (2796 aged 5 – 7 and 2625 aged 9-11 years) in Dresden, Germany, was examined in 1995/96 using the International Study of Asthma and Allergies in Children Phase II protocol (questionnaire, lung function testing, bronchial challenge with 4.5% saline, details of the methods see Weiland et al 1999). Lung function tests were not performed in children who reported to have a cold. 7.5% of the children had been wheezing in the past 12 months and 6.8% had been diagnosed as asthmatics by a doctor. 26.6% of the children were exposed to maternal smoking (further details of the study population see Hirsch/Weiland/Mutius et al 1999). The children's home addresses were assigned to Gauss-Krüger-(GK) coordinates in order to use them in a geographical information system (Arc Info, Environmental Systems Research Institute, Redlands Ca).

Calculation of the individual background exposure

In 1994/95, outdoor air pollution in the populated area of Dresden had been monitored at 182 points in a 1km x 1km grid in the Gauss-Krüger (GK)-coordinate system (detailed description of the method see Hirsch/Weiland/Mutius et al 1999). Only those 114 grid points which were located more than 300m away from streets with dense traffic (> 5000 cars per day) were used to calculate city background NO_2 levels. A visual exploration of coloured plots showed that the spatial distribution of background NO_2 values was represented best by a quadratic function with values decreasing monotonously from the city centre to the suburbs. A least-square regression function (Equation 1) was then calculated that describes yearly mean NO_2 concentrations at the children's addresses depending on their GK coordinates (x,y in units of 10^4 m).

Equation 1: Regression function of measured NO_2 background concentrations

$$NO_2\ (x,y) = 24.778+5.46*(x-540) + 5.812*(y-565) -3.641*(x-540)^2 +0.34*(x-540)*(y-565) -4.219*(y-565)^2\ ((g/m^3)$$

In this equation the spatial deviation of a point from the lower left corner (GK coordinates $x = 540 * 10^4$; $y = 565 * 10^4$) of a rectangle covering the area of greater Dresden ($x = 540 * 10^4 - 543 * 10^4$); $y = 565 * 10^4 - 567.2 * 10^4$) determines the NO_2 concentration.

The relative deviation of these estimated values from values measured at 9 randomly chosen points which were excluded from the model calculations for the purpose of validation was 22 (mean) +/- 18 (SD)%.

Calculation of the individual traffic-related exposure

In a second step a traffic-related exposure estimate was calculated. Census data on traffic characteristics (density, velocity, types of cars) on main streets in Dresden in 1994 were obtained by continuous counts at 8 main junctions and discontinuous counts at 160 additional monitoring points (Heusch-Boesefeldt GmbH 1995). Using these data in conjunction with information on metereologic conditions, local building structures and emission factors for different types of cars (Umweltbundesamt 1994) model calculations of NO_2 concentrations at the roadside (+/- 15m from the middle of the road) were performed (Lohmeyer 1996).

The modelled roadside concentrations exceeded the background concentration calculated in equation 1 for all but 30 children living within 300m distance from the next street with dense traffic (n=4592). In accordance to validated models from the SAVIAH (Small Area Variations in Air quality and Health) project (Briggs et al 1997) the excess road side concentrations were then individually weighted in two distance categories:

Weight = 1	if distance $\leq$ 30m
Weight = 1 – (distance in m – 30)/270	if distance > 30m and $\leq$ 300m

For children living > 300m distant from roads with heavy traffic the background estimate was used as traffic-related estimate, because in the SAVIAH models local traffic did not affect NO_2 concentrations at points more than 300m away. The background estimates were also used for those 30 children living within 300m from big roads whose traffic-related estimates were lower than the background values.

Table 1 Prevalence of respiratory symptoms and diseases, reduced pulmonary function, and atopy in children* by categories of exposure to NO2

a) Estimated background exposure to NO2 at home address**

	- 26 $\mu g/m^3$	- 27 $\mu g/m^3$	- 28 $\mu g/m^3$	- 28.5 $\mu g/m^3$	> 28.5 $\mu g/m^3$	P value***
Symptoms in the past 12 months						
Wheeze	90/1358 (6.6 %)	61/807 (7.6 %)	99/1248 (7.9 %)	43/543 (7.9 %)	105/1369 (7.7 %)	0.30
Morning cough	123/1355 (9.1 %)	82/811 (10.1 %)	144/1251 (11.5 %)	60/541 (11.1 %)	180/1371 (13.1 %)	0.00065
Pulmonary function						
Bronchial hyperresponsiveness (4.5 % NaCl)	33/148 (22.3 %)	15/97 (15.5 %)	37/232 (15.9 %)	18/146 (12.3 %)	53/333 (15.9 %)	0.12
FEV 1 (% pred.) < 85 %	18/224 (8.0 %)	4/110 (3.6 %)	21/283 (7.4 %)	7/157 (4.5 %)	22/363 (6.1 %)	0.43
$FEF_{25-75\%}$ (% pred.) < 70 %	32/222 (14.4 %)	13/107 (12.1 %)	42/281 (14.9 %)	18/156 (11.5 %)	45/357 (12.6 %)	0.49

b) Estimated exposure to NO2 at home address based on information on local traffic**

	- 29 $\mu g/m^3$	- 32.5 $\mu g/m^3$	- 36 $\mu g/m^3$	- 39.5 $\mu g/m^3$	> 39.5 $\mu g/m^3$	P value***
Symptoms in the past 12 months						
Wheeze	95/1339 (7.1 %)	79/1069 (7.4 %)	67/864 (7.8 %)	68/701 (9.7 %)	89/1352 (6.6 %)	0.93
Morning cough	138/1336 (10.3 %)	129/1074 (12.0 %)	92/861 (10.7 %)	76/703 (10.8 %)	154/1355 (11.4 %)	0.65
Pulmonary function						
Bronchial hyperresponsiveness (4.5 % NaCl)	47/227 (20.7 %)	31/226 (13.7 %)	23/145 (15.9 %)	21/130 (16.2 %)	34/228 (14.9 %)	0.23
FEV 1 (% pred.) < 85 %	16/287 (5.6 %)	16/243 (6.6 %)	16/175 (9.1 %)	13/162 (8.0 %)	11/270 (4.1 %)	0.65
$FEF_{25-75\%}$ (% pred.) < 70 %	36/280 (12.9 %)	32/241 (13.3 %)	25/173 (14.5 %)	25/161 (15.9 %)	32/268 (11.9 %)	0.95

* 'The results are presented for 5 - 7 and 9 -11 year olds combined.

** Categories of NO2 exposure are characterized by their upper limits except for the highest category. The extreme categories represent larger ranges of exposure in order to achieve sufficiently large sample sizes.

*** Mantel-Haenszel-Chi-Square test for linear trend

The traffic-related exposure estimates were validated at 7 continuous monitoring stations (mean relative deviation 12.0%; SD +/- 12%).

Statistical analysis

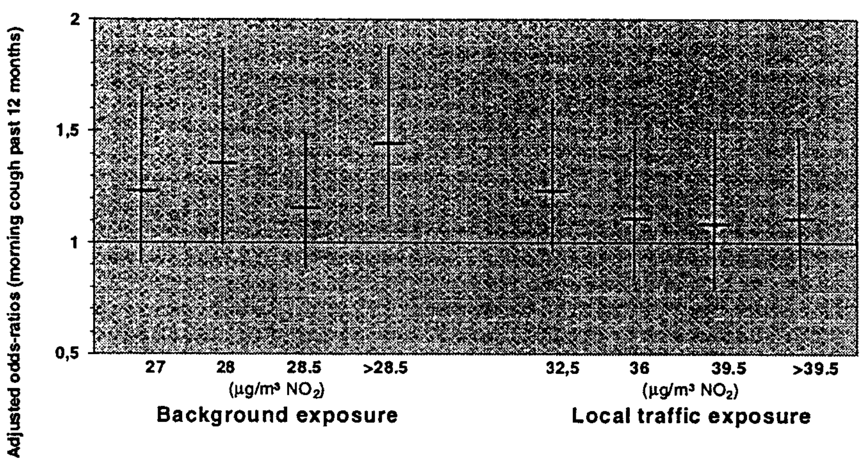
Both background exposure and traffic-related estimates were then alternatively related to health data for each child. Because the range of exposure was far greater when using the traffic-related estimates, five categories of approximately equally-sized exposure ranges were introduced for each of the two exposure estimates. The association of NO_2 exposure with respiratory symptoms and pulmonary function was analysed bivariately and in a multivariate regression model controlling for a number of potential confounders. Software for all calculations was SPSS (Chicago, IL) for Microsoft Windows 6.01.

Results

Wheeze in the past 12 months was reported by 398/5325 (7.5%) of the parents. Cough in the morning was reported for 589/5329 (11.1%) of the children. Cough but not wheeze was significantly more frequent in the older than in the younger age group (12.0 vs. 10.2 %, $p < 0.05$). Among the 9-11 year olds, 156/956 (16.3%) showed bronchial hyperresponsiveness.

The estimated background exposure ranged from 19.3 to 29.0μg NO_2/m3 air (median 27.5μg/m3). Exposure estimates including information on local traffic ranged from 19.5 to 63.7μg/m3 (median 33.3μg/m3). Increasing background exposure was associated with higher prevalences of cough in the morning while increasing exposure to traffic-related NO_2 was not (Table 1). Similar results were found in subgroups presumably more directly affected by traffic exposure (children living in dwellings at low [</= 1st] floors or with a window towards the street in the child's bedroom) (data not shown).

Adjustment for potential confounders (listed in legend to Figure 1) in a multiple logistic regression model did not alter these associations substantially. An address in the highest quintile of background exposure (> 28.5μg NO_2/m3 air) was associated with a 40% increase in the risk for morning cough (aOR 1.4; 1.1 – 1.9) as compared to the baseline category (</= 26μg NO_2 /m³ air). In contrast, no increased risk was observed for increasing exposure to local traffic (Figure 1).



Discussion

In the population investigated increasing exposure to background levels of NO_2 was positively associated with cough in the morning. In contrast, an exposure estimate based on information on local traffic exposure was not associated with respiratory symptoms. Confirmatory to the work of others (Ciccone et al 1998; Dockery et al 1989; Braun-Fahrländer 1997), wheeze, FEV 1, $FEF_{25-75\%}$, and bronchial hyperresponsiveness were not significantly associated with any of the two exposure estimates. The exposure estimates had been validated at continuous monitoring stations with acceptable results. There are two possible explanations for our observation:

1. NO_2 is probably only a marker but not the most important toxic component of traffic exhaust. For example, some studies have demonstrated an association of black smoke with respiratory effects (Brunekreef et al 1997; van Vliet et al 1997). It could be hypothesized that traffic-related NO_2 estimates are less well associated with black smoke than background NO_2 estimates. However, in the population investigated here, no significant associations were found between estimates of traffic-related black smoke and respiratory symptoms as well (Hirsch et al 2001).
2. Children spend only a minor part of the day at the side of the road where they live (Özkaynak 1999; Spier et al 1992). Therefore traffic-related exposure estimates may induce a considerable degree of misclassification. This holds true even for children living in dwellings at low floors or in rooms with a window towards the street. Such windows may be closed most of the time due to traffic noise or other traffic-related inconveniences.

In conclusion, this analysis shows a stronger association of background NO_2 estimates with respiratory symptoms as compared to estimates including information on local traffic. The results question the concept of determining pollutant exposure by measuring traffic exposure at the address of residence without consideration of background pollution and individual time-activity patterns.

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