



Original Contribution

Living near Main Streets and Respiratory Symptoms in Adults

The Swiss Cohort Study on Air Pollution and Lung Diseases in Adults

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The Swiss Cohort Study on Air Pollution and Lung Diseases in Adults (SAPALDIA), conducted in 1991 (SAPALDIA 1) in eight areas among 9,651 randomly selected adults aged 18–60 years, reported associations among the prevalence of respiratory symptoms, nitrogen dioxide, and particles with an aerodynamic diameter of less than 10 $\mu\text{g}/\text{m}^3$. Later, 8,047 subjects reenrolled in 2002 (SAPALDIA 2). The effects of individually assigned traffic exposures on reported respiratory symptoms were estimated, while controlling for socioeconomic and exposure- and health-related factors. The risk of attacks of breathlessness increased for all subjects by 13% (95% confidence interval: 3, 24) per 500-m increment in the length of main street segments within 200 m of the home and decreased in never smokers by 12% (95% confidence interval: 0, 22) per 100-m increment in distance from home to a main street. Living within 20 m of a main street increased the risks of regular phlegm by 15% (95% confidence interval: 0, 31) and wheezing with breathing problems by 34% (95% confidence interval: 0, 79) in never smokers. In 2002, the effects related to road distance were different from those in 1991, which could be due to changes in the traffic pollution mixture. These findings among a general population provide strong confirmation that living near busy streets leads to adverse respiratory health effects.

cohort studies; environmental exposure; geographic information systems; motor vehicles; prevalence; respiratory tract diseases; Switzerland

Abbreviations: OR, odds ratio; PM_{10} , particles with an aerodynamic diameter of less than 10 $\mu\text{g}/\text{m}^3$ ($\text{PM}_{2.5}$ defined analogously); SAPALDIA, Swiss Cohort Study on Air Pollution and Lung Diseases in Adults.

Ambient air pollution is recognized to have adverse effects on respiratory health (1–3). In the first cross-sectional survey of the Swiss Cohort Study on Air Pollution and Lung Diseases in Adults (SAPALDIA), fixed-site annual means of particles with an aerodynamic diameter of less than 10 $\mu\text{g}/\text{m}^3$ (PM_{10}) and nitrogen dioxide were found to

be associated with respiratory symptoms (4) and lung function (5) in 1991. Moreover, differences in nitrogen dioxide exposure levels within study areas were found to be associated with differences in lung capacity (6). These results have contributed to the implementation of World Health Organization air quality standards in the 1990s (7). Subsequent

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debate about cost-effective measures to reduce the adverse health effects of outdoor air pollution has triggered research efforts to identify and quantify sources of particles and the respective health effects (2, 8–12).

Evidence is growing that particles from mobile sources are associated with daily mortality or the risk of cardiopulmonary mortality (9, 13–15). Several studies have reported adverse respiratory effects from traffic exposures among children (16–20) and occupationally traffic-exposed policemen (21) and street cleaners (22). In a US veterans study, an increased risk of persistent wheeze was associated with living within 50 m of a major roadway (23), while an increased risk of chronic bronchitis was found for those living at busy roads in a random sample of women in Germany (24).

No studies thus far have examined traffic effects in a general adult population. We used data from SAPALDIA conducted in 1991 (SAPALDIA 1) and 2002 (SAPALDIA 2) to investigate associations between traffic exposures and the 12-month period prevalence of respiratory symptoms in a random adult population sample. We tested the hypotheses that a greater distance of the home address to the closest main street is associated with a reduced risk of respiratory symptoms and that a denser street network around the home, as well as living very close to a main street, increases such risks. In addition, we evaluated whether the effect estimates in 1991 differed from those in 2002 because of the changes in automobile emissions and, thus, ambient concentrations of traffic-related pollutants (25–27).

MATERIALS AND METHODS

Study population and design

SAPALDIA, commenced in 1991, aims at investigating the long-term health effects of air pollution in a general adult population. Eight study areas were chosen to represent various conditions of geography, climate, degree of urbanization, and air pollution in Switzerland. In four urban (Aarau, Basel, Geneva, Lugano), two rural (Payerne and Wald), and two alpine (Montana and Davos) areas, random population samples of persons aged 18–60 years, who had been residents in the respective area for at least 3 years, were drawn from the local registries of inhabitants in 1991 (28). Of 9,651 participants examined in 1991, 8,047 subjects re-enrolled in the study in 2002 and provided basic information on health status (29). In the current analysis, information from 3,500 subjects of SAPALDIA 2 had to be excluded because of missing reported symptoms ($n = 999$) and other insufficient information ($n = 2,501$) (Web table 1). (This information is described in a supplementary table posted on the *Journal's* website (<http://aje.oxfordjournals.org/>.) Ethical approval for the study was given by the central ethics committee of the Swiss Academy of Medical Sciences and the cantonal ethics committees for each of the eight examination areas. Participants were required to give written consent before any part of the health examination was conducted. Detailed descriptions of the 1991 and 2002 examinations can be found elsewhere (28, 29).

Detailed characteristics of the cohort are given in Web table 1. From 1991 to 2002, the proportion of current smok-

ers had dropped, environmental tobacco smoke exposures had clearly decreased, and the proportion of Swiss nationals had increased. Exclusion criteria for the current analyses were low quality of geocoding, missing covariates, no available symptom data, living less than 1 year at the SAPALDIA 2 address, or living outside the SAPALDIA study areas. For SAPALDIA 1 subjects, those excluded did not differ from those included in the analysis for most covariates, with the exception of a significantly smaller proportion of those excluded reporting current occupational exposures and never smoking. Among SAPALDIA 2 subjects, those excluded differed from those included in the analyses: They were more likely to be male, current smokers, and younger, and they reported less environmental tobacco smoke and occupational exposures.

Questionnaire-based assessment of respiratory symptoms

Health examinations conducted at the eight local centers in 1991 and 2002 included, among others, a standardized, computer-assisted interview based on the European Community Respiratory Health Survey questionnaire (30) and measurements for atopy (total immunoglobulin E and allergen-specific immunoglobulin E against a mix of common inhalant allergens (Phadiatop and Pharmacia CAP System; Pharmacia Diagnostics AB, Uppsala, Sweden)). A skin prick test for eight inhalant allergens was conducted in 1991. The questionnaire in both surveys consisted of identical questions on the history of respiratory symptoms, allergic diseases, general health, living and working environment, smoking habits, and exposure to environmental tobacco smoke. The following respiratory symptoms, reported for the 12 months preceding the interview, were used as health outcomes in this analysis: “attacks of breathlessness,” “wheezing with breathing problems,” and “wheezing without colds” (symptoms typically associated with asthma) and “regular cough” and “regular phlegm” (typically associated with bronchitis); definitions are given in the Appendix.

Assignment of individual exposure estimates

To take into account the previously documented spatial variability of traffic-related pollution within an area (12, 31–38), we used geographic information system data to assign individual traffic exposure estimates at each subject's residence, where people spend the majority of their time (39). Findings that indoor levels of traffic-related compounds are highly correlated with outdoor levels (40–42) and that front-door levels of black smoke are significant predictors of personal black smoke exposures (43) justify using traffic estimates at the home address to approximate individual traffic exposure. Subjects' 1991 and 2002 addresses were geocoded by matching the addresses to the building registry of the Swiss Federal Statistical Office (44). Only high-quality matches, defined as matching at the house number level or to the nearest neighbor's house number, were used for this analysis to reduce exposure misclassification. The distance from the 1991 and 2002 home coordinates to the closest main street (major road) or highway (refer to Appendix

TABLE 1. Prevalences of reported respiratory symptoms in the SAPALDIA* cohort population, Switzerland, 1991 and 2002

Respiratory symptoms (last 12 months)	SAPALDIA 1 (1991)				SAPALDIA 2 (2002)			
	Subjects in GEE* model (<i>n</i> = 8,452) (%)	Subjects excluded†		<i>p</i> value‡	Subjects in GEE model (<i>n</i> = 4,547) (%)	Subjects excluded§		<i>p</i> value‡
		No.	%			No.	%	
Attacks of breathlessness, day or night	8.7	1,194	10.4	0.061	7.7	2,498	8.7	0.147
Wheezing with breathing problems	6.1	1,196	8.6	0.001	6.3	2,501	7.2	0.142
Wheezing without colds	7.3	1,196	10.6	<0.001	7.9	2,501	8.7	0.266
Regular cough	16.4	1,194	18.3	0.090	16.3	2,495	16.9	0.564
Regular phlegm	13.0	1,194	15.8	0.007	15.1	2,494	13.8	0.148

* SAPALDIA, Swiss Study on Air Pollution and Lung Diseases in Adults; GEE, generalized estimating equation.

† Subjects with geocoding on street or community level (*n* = 417) or with one or more missing covariates (*n* = 782).

‡ Comparison of subjects in GEE model and of excluded subjects using chi-square tests.

§ Subjects with geocoding on street or community level (*n* = 619), living less than 1 year at the SAPALDIA 2 address (*n* = 438), living outside the study region (*n* = 549), or with one or more missing covariates (*n* = 895). For 999 subjects, no data on symptoms were available.

table 1 for definitions), as well as the length of main street segments within a 200-m perimeter around the home coordinates, was computed on the basis of VECTOR25 (Swiss Federal Office of Topography, Wabern, Switzerland; <http://www.swisstopo.ch>) (45). In addition, a binary variable was created to indicate whether or not there was a main street within 20 m of the home.

In addition, regional background concentrations of PM₁₀ in 1990 and 2000 were estimated by a dispersion model at a 200- × 200-m resolution (46, 47) and assigned to each participant's geocoded addresses in 1991 and 2002, respectively. The background concentration accounts for imported primary and secondary particles, as well as domestic biogenic particles, and depends on altitude as a result of inversions. The modeled PM₁₀ concentrations (mean: 22.6 µg/m³) were validated against PM₁₀ measurements (mean: 21.4 µg/m³) at 44 fixed monitoring sites in Switzerland in 2000, resulting in a Pearson's correlation coefficient of 0.74 (46).

Statistical analysis

Generalized estimating equation models were used to assess associations between the odds of symptom reports and the proxy variables for traffic exposure. With from one to two observations per subject, the correlation of outcomes within a subject could be described by a compound symmetry model (xtgee function in STATA statistical software (48)). Robust standard errors were estimated with the Huber/White/sandwich estimator of variance (48). The effects of traffic exposures on reported respiratory symptoms were estimated with variables combining exposures at both time points (common slope). To obtain separate effect estimates for 1991 and 2002, we used the same model with two survey-specific exposure variables (separate slopes).

The generalized estimating equation regression models controlled for a standard set of socioeconomic factors (sex, age, low education, and nationality), exposure-related factors (active and passive smoking, current and past occupational exposures, and regional background PM₁₀), and health-related factors (atopy, early respiratory infections,

family history of asthma and atopy, maternal smoking, and body mass index) as previously used in SAPALDIA 1 (4). In preliminary analyses, we tested quadratic terms for age and body mass index but could not find evidence for nonlinear associations with these two covariates. Dummy variables for the month of interview and the study area were also included. In the SAPALDIA 2 data set, records from subjects living outside a SAPALDIA study area were excluded. Separate analyses were conducted for never smokers, urban and rural/alpine regions, and men and women, respectively.

For sensitivity analyses, we repeated the models, excluding subjects with inconsistent information on smoking status. Furthermore, we evaluated the impact of exposure misclassification on the effect estimates by first restricting analyses to subjects with geocoding of addresses at the house number level and then including additional subjects with low-quality geocoding of addresses. We also ran models with side street variables for the proxy variables for traffic exposure.

All statistical analyses were conducted with STATA, version 8.0 SE, statistical software (48).

RESULTS

Table 1 presents the crude prevalence of reported respiratory symptoms for the 12 months preceding each interview. In both SAPALDIA 1 and SAPALDIA 2, the prevalence ranged between 6 percent (wheezing with breathing problems) and 16 percent (regular cough). Subjects excluded from the SAPALDIA 1 analysis generally had a higher prevalence of reported symptoms than did those included. Never smokers consistently reported less symptoms in 1991 (4) and 2002 (data not shown).

In 1991, participants lived at an average distance of 84 m to a main street, with an average of 660 m of main street segments within 200 m of their homes (table 2). Twenty percent of the participants lived within 20 m of a main street. In 2002, the corresponding averages changed to 95 m and 600 m, respectively, and only 17 percent of the participants lived within 20 m of a main street. Generally, urban

TABLE 2. Distribution of the traffic exposure proxies in the SAPALDIA* cohort population, Switzerland, 1991 and 2002

No.	Distance to the next main street (m)										Length of main street segments within 200 m (m)					Living within 20 m of main street	
	Mean	SD*	Minimum	25th	50th	75th	Maximum	Mean	SD	Minimum	25th	50th	75th	Maximum	No.	%	
SAPALDIA 1 (1991)																	
All subjects†	84	93	1	23	54	110	2,684‡	660	411	0	387	638	930	2,666	1,722	20	
Urban	67	65	1	21	46	88	487	803	416	0	516	780	1,064	2,666	1,041	23	
Rural and alpine	104	115	1	26	68	141	2,684‡	493	336	0	286	419	731	1,810	681	17	
Men	84	90	1	23	53	109	932	659	414	0	383	640	930	2,666	883	21	
Women	4,322	85	1	24	55	110	2,684‡	661	409	0	390	637	932	2,384	839	19	
Never smokers	3,761	96	5	24	57	116	932	642	413	0	374	616	909	2,384	728	19	
Current smokers	2,793	77	1	22	48	109	602	694	410	0	398	678	968	2,666	630	23	
Former smokers	1,898	106	1	24	57	111	2,684‡	647	406	0	379	620	902	2,133	364	19	
SAPALDIA 2 (2002)																	
All subjects†	95	96	1	26	64	127	907	600	398	0	346	567	857	2,174	763	17	
Urban	2,374	79	1	24	54	102	880	726	414	0	415	711	1,014	2,174	448	19	
Rural and alpine	2,173	112	1	30	79	153	907	462	329	0	244	406	684	1,896	315	15	
Men	2,123	96	1	27	66	126	907	586	387	0	345	550	838	2,174	344	16	
Women	2,424	94	1	26	62	127	907	612	407	0	348	577	874	2,138	419	17	
Never smokers	2,161	99	3	28	67	131	907	586	402	0	328	546	846	2,138	352	16	
Current smokers	1,058	91	5	26	63	120	880	616	385	0	365	600	874	1,988	169	16	
Former smokers	1,328	90	1	25	60	122	540	609	401	0	361	571	869	2,174	242	18	

* SAPALDIA, Swiss Study on Air Pollution and Lung Diseases in Adults; SD, standard deviation.

† Subjects included in the generalized estimating equation models (with high-quality geocoding and a complete set of covariates).

‡ Excluding one subject with a distance of 2,684 m to the closest main street results in a maximum distance of 932 m.

participants lived closer to main streets within a denser street network than did their rural counterparts. Never smokers lived farther away from main streets within a lighter street network than did current smokers. In the rural but not the urban areas, lower social status was associated with living close to a main street.

Table 3 shows the influence of distance on respiratory symptoms estimated by the generalized estimating equation regression model with and without adjustment for covariates. For each 100-m increment in distance to the closest main street, the adjusted risk of reporting regular phlegm was reduced by 7 percent. For the other symptoms, a tendency for reduced risks was observed (odds ratio (OR) < 1). In never smokers, each 100-m increment in distance to the closest main street was associated with a 12 percent reduced risk for attacks of breathlessness.

The length of main street segments within 200 m around the home was positively associated with a 13 percent (per 500 m) increased risk of attacks of breathlessness in all subjects (and 20 percent increased risk in never smokers who also had a higher risk of wheezing without cold (18 percent)). For other symptoms, a tendency for increased risks was observed (OR > 1).

Living within 20 m of a main street was associated with a 15 percent increased risk of regular phlegm in all subjects and a 34 percent increased risk of wheezing with breathing problems in never smokers. Larger effect estimates were obtained without adjustment for potential confounders in all subjects but not in never smokers. Removing regional background PM₁₀ from the model changed the effect estimates only very slightly (data not shown).

Figure 1 shows the adjusted odds ratios for attacks of breathlessness for the second, third, and fourth quartiles of distance to the closest main street and length of main street segments, relative to the first quartile. It suggests consistent exposure-response associations for both traffic proxies, particularly among never smokers.

Separate analyses for the four urban and four rural/alpine areas resulted in rather unstable estimates, and there was no systematic pattern distinguishing associations in urban and rural areas (data not shown). Evidence for adverse effects on respiratory health from living close to side streets was not found (data not shown). Excluding subjects with inconsistent information on smoking status (*n* = 275) had little impact on the effect estimates. Generally, restricting the analysis to subjects with geocoding matched on house numbers (i.e., excluding those with nearest neighbor matches) resulted in stronger effect estimates, while inclusion of subjects with low quality of geocoding (on street or community level) resulted in slightly weaker effect estimates, as would be expected for reduced and increased exposure misclassification. Comparisons of the effect estimates between SAPALDIA 1 and SAPALDIA 2 suggest that traffic effects on the reported respiratory symptoms became weaker from 1991 to 2002. Effect estimates for distance to main street changed relatively little, while effects for length of main street segments within 200 m disappeared. In contrast, the estimated effects on wheezing from living within 20 m of a main street became stronger in 2002, particularly in men where the difference for wheezing without a cold (from

TABLE 3. Unadjusted and adjusted odds ratios and 95% confidence intervals of reported respiratory symptoms associated with traffic exposure proxies for the SAPALDIA* cohort population, Switzerland, 1991 and 2002

Respiratory symptom during last 12 months	Entire sample (n = 12,999)†				Never smokers (n = 5,922)‡			
	Unadjusted		Adjusted§		Unadjusted		Adjusted§	
	Odds ratio	95% confidence interval	Odds ratio	95% confidence interval	Odds ratio	95% confidence interval	Odds ratio	95% confidence interval
Distance to closest main street (per 100 m)								
Attacks of breathlessness	0.86	0.79, 0.94	0.93	0.85, 1.01	0.84	0.75, 0.94	0.88	0.78, 1.00
Wheezing with breathing problems	0.93	0.85, 1.02	0.95	0.87, 1.04	0.90	0.79, 1.04	0.91	0.79, 1.05
Wheezing without cold	0.91	0.84, 0.99	0.97	0.89, 1.06	0.89	0.78, 1.03	0.91	0.78, 1.06
Regular cough	0.91	0.87, 0.97	0.96	0.90, 1.01	0.98	0.90, 1.08	1.00	0.91, 1.10
Regular phlegm	0.88	0.82, 0.94	0.93	0.87, 0.99	0.97	0.88, 1.07	1.01	0.91, 1.12
Length of main street segments within 200 m (per 500 m)								
Attacks of breathlessness	1.23	1.14, 1.33	1.13	1.03, 1.24	1.26	1.12, 1.41	1.20	1.05, 1.38
Wheezing with breathing problems	1.10	1.00, 1.21	1.09	0.98, 1.21	1.13	0.97, 1.31	1.15	0.97, 1.35
Wheezing without cold	1.15	1.06, 1.24	1.06	0.97, 1.16	1.17	1.01, 1.34	1.18	1.01, 1.39
Regular cough	1.06	1.00, 1.12	1.00	0.94, 1.07	1.10	0.99, 1.22	1.08	0.96, 1.21
Regular phlegm	1.13	1.07, 1.20	1.06	0.98, 1.13	1.11	1.00, 1.23	1.06	0.94, 1.20
Living within 20 m of a main street								
Attacks of breathlessness	1.21	1.03, 1.41	1.16	0.99, 1.35	1.09	0.85, 1.40	1.06	0.82, 1.37
Wheezing with breathing problems	1.24	1.04, 1.48	1.19	0.99, 1.43	1.34	1.00, 1.78	1.34	1.00, 1.79
Wheezing without cold	0.99	0.83, 1.17	0.94	0.78, 1.12	1.03	0.75, 1.41	1.05	0.76, 1.45
Regular cough	1.03	0.91, 1.16	0.96	0.85, 1.09	0.94	0.75, 1.18	0.93	0.75, 1.17
Regular phlegm	1.18	1.03, 1.34	1.15	1.00, 1.31	1.06	0.84, 1.33	1.06	0.84, 1.34

* SAPALDIA, Swiss Study on Air Pollution and Lung Diseases in Adults.

† n = 12,994–12,999 observations from 8,553–8,555 subjects.

‡ n = 5,921–5,922 observations from 3,819–3,820 subjects.

§ Estimated odds ratios for the SAPALDIA cohort adjusted for sex, age, education, nationality, active and passive smoking, current and past occupational exposures, atopy, early respiratory infections, family history of asthma and atopy, maternal smoking, body mass index, regional background particles with an aerodynamic diameter of less than 10 $\mu\text{m}/\text{m}^3$, month of interview, and area.

OR = 0.95 in 1991 to OR = 1.46 in 2002) reached statistical significance ($p = 0.04$).

DISCUSSION

We found evidence that residential exposure to traffic is associated with asthmatic and bronchitic symptoms, in par-

ticular with attacks of breathlessness, wheezing with breathing problems, wheezing without a cold, and regular phlegm. Our findings are consistent with those of previous epidemiologic studies on traffic exposures that reported associations with persistent wheeze (23), bronchitic symptoms (21–23), and chronic bronchitis (24) in adults and with wheeze (17–19) and cough (18) in children. The strengths of our study

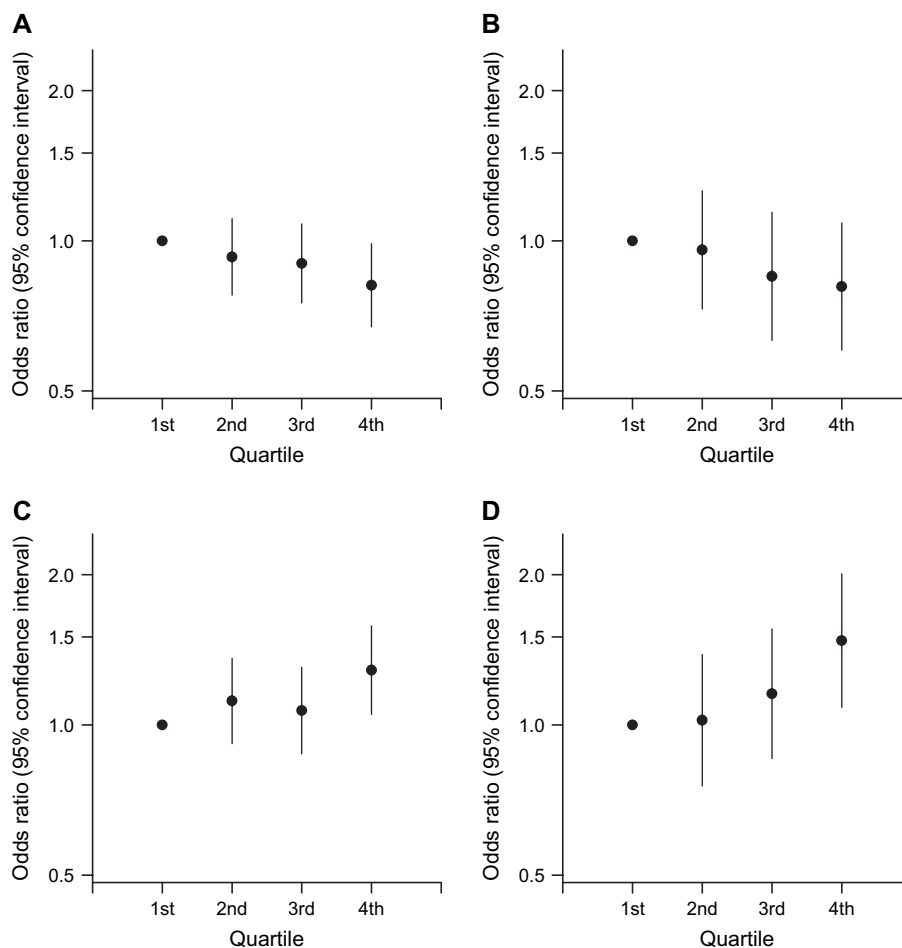


FIGURE 1. Adjusted odds ratios (and 95% confidence intervals) for reported attacks of breathlessness by quartiles of “distance to the closest main street” (first: 0–23 m; second: 24–58 m; third: 59–117 m; fourth: 118–2,684 m, top) and by quartiles of “length of main street segments around the home address” (first: 0–366 m; second: 367–596 m; third: 597–892 m; fourth: 893–2,666 m, bottom) for the entire sample and for never smokers (the lowest quartile category serving as the reference group) in the SAPALDIA cohort population, Switzerland, 1991 and 2002. A, distance (all subjects); B, distance (never smokers); C, length (all subjects); D, length (never smokers). For information on the adjustment variables, refer to the “Statistical analysis” section of the text. SAPALDIA, Swiss Cohort Study on Air Pollution and Lung Diseases in Adults.

include its population-based design and the individually assigned traffic exposures using objective data. We demonstrated consistent results using three different proxies of traffic exposure. An exposure-response association was clearly shown for attacks of breathlessness. We found a tendency for stronger respiratory effects in never smokers and in men. In sensitivity analyses, the effect estimates proved to be stable. The effect estimates in 2002 were weaker than those in 1991, especially in men. That the observed associations were not confounded by regional background PM_{10} further supports the hypothesis that living close to main streets leads to health effects that cannot be attributed to background air pollution.

Period prevalence of respiratory symptoms

As the reported symptoms reflect the period prevalence during the 12 months preceding the surveys, they may cap-

ture primarily the response to exposure during the respective 12-month periods. The assigned traffic exposures also relate to the individual residences during the respective time periods. The underlying hypothesis that traffic exposures during these 12 months are the most relevant exposure terms is supported by findings of a prospective study in children, where respiratory symptoms fluctuated concurrently with annual pollutant means (49).

Changes over follow-up

One weakness of using proxies for traffic exposure is that the actual scaling or exposure levels of traffic exhaust at the two time points are likely not comparable. Emission factors of vehicles have generally decreased over the 11-year follow-up period, although not to the same extent for all components and vehicle categories (25). Between 1990 and 2000, the vehicle road performance (vehicle km/year) has

increased by about 16 percent in Switzerland (25). The composition of the Swiss car fleet has also changed, with a substantial increase of cleaner Euro1 and Euro2 cars and diesel cars meeting European antipollution rules (from 6 to about 10 percent) (25). These changes have led to an overall 36 percent decrease of traffic-related nitrogen oxide emissions (25), resulting in a similar decrease of nitrogen oxide concentrations at urban monitoring sites close to traffic, while levels of primary pollutant decreased only slightly at rural and background sites (50). This implies that the underlying quantitative exposure of the three traffic proxies has changed since 1991, which may result in a change of the proxy gradient and lead to weaker or stronger relative risks per exposure unit. Our data show, indeed, a trend to weaker or even vanishing associations in 2002 for most of the symptoms with all three exposure proxies. The fact that there are exceptions suggests that these changes did not affect exposure proxies and symptoms uniformly. The general increase in road performance in Switzerland has led to more traffic congestion. Together with the increased share of diesel cars, these secular trends may have resulted in higher proportions of diesel particles and of other primary pollutants emitted by stop-and-go traffic compared with moving traffic. This might explain the enhanced associations of wheezing symptoms with "living within 20 m of a main street," in line with a recent study demonstrating that children living close (<100 m) to stop-and-go traffic had an increased risk for wheezing without a cold (51). Our finding is also consistent with increased resuspended particulate matter from traffic ingestion, although the specific toxicologic relevance of exhaust versus resuspended particles is not yet clear.

On average, the SAPALDIA study population experienced a reduction of exposure to main streets between the two surveys. The SAPALDIA 2 subjects lived at a greater distance to the closest main street and were surrounded by less main street segments, and a lower proportion of them was living very close to a main street. This reflects the tendency of subjects to move to agglomerations and rural areas. However, such shifts on the proxy exposure scales would not affect risk estimates if traffic characteristics had not changed.

Limitations

Although the exposure proxies are indirect measures of traffic-related exposure, there is evidence that the levels of traffic-related components of air pollution are associated with the distance from a main street (31, 32) and with the street density around a location (52). In Switzerland, the proportion of traffic-related compounds was higher at curbside sites than at background and rural sites (53). In a Dutch study, the distance to the nearest major road explained 28 percent of the variation of PM_{2.5} filter absorbance, while the distance to the closest road explained only 3 percent (52). In the SAPALDIA cohort, no health effects were observed for the side street variables. Second, the surrogates of traffic exposure are proxies for the exposure level at home outdoors. Studies reporting indoor levels of traffic-related compounds to be highly correlated with outdoor levels (40–42) suggest that outdoor levels are also relevant for total personal ex-

posures to traffic (39). Another limitation of the surrogates is that they do not take into account individual differences in the time spent at home and in other environments, such as workplaces or in traffic while commuting (39). Yet, personal carbon monoxide measurements showed that the time spent in traffic increases short-term peak exposures but not 48-hour average exposures (54). Average daily carbon monoxide exposures were found to be dominated by the home location (54) and by indoor levels at home (55), where most of the time is spent (39). These findings suggest that long-term exposures to traffic-related pollutants may be sufficiently captured by estimates for the home outdoors. By including fixed-area effects in the models, we estimated average effects within but not across study areas, thereby diminishing comparability problems. Another limitation of the study is that the health outcomes are self-reported symptoms. Even if awareness of symptoms varied more strongly with traffic exposure than symptom prevalence, our findings would indicate that traffic exposure influences the quality of life. Further, a number of subjects had to be excluded from analysis because of missing data or low quality of geocoding. This might raise concern about potential selection bias. However, we examined whether baseline associations between respiratory symptoms and traffic exposure proxies differed between subjects having been included in our SAPALDIA 2 analysis and subjects who were not. Differences could be seen for attacks of breathlessness, where associations appeared to be weaker among subjects not included in the follow-up analysis but, for all the other symptoms with statistically significant adjusted odds ratios in table 3, the differences were small.

Conclusions

Our results provide evidence for the adverse effects of traffic exposures on respiratory health, consistent with previous studies associating traffic exposures with respiratory symptoms (17–19, 21–23), increased mortality (9–11, 13–15), and childhood asthma (16, 20). We conclude that living close to main streets or in a dense street network increases the risks for certain respiratory symptoms in adults, particularly for asthma-related symptoms such as attacks of breathlessness and wheezing and for bronchitic symptoms such as regular cough and phlegm. These effects appear to be independent of modeled regional background PM₁₀. Our findings in a random sample of the adult population of Switzerland provide further support to the hypothesis that traffic exhausts are relevant to respiratory health.

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APPENDIX

Definition of reported respiratory symptoms

Respiratory symptoms are defined as a positive answer to the following question(s): attacks of *breathlessness*: “Have you had an attack of shortness of breath that came on during the day when you were at rest at any time in the last 12 months?” or “Have you been awakened by an attack of shortness of breath at any time in the last 12 months?”; *wheezing*: “Have you had wheezing or whistling in your chest at any time in the last 12 months?”; *wheezing with breathing problems*: wheezing and “Have you had breathing problems when you had this wheezing or whistling?”; *wheezing without colds*: wheezing and “Have you had this wheezing or whistling when you did not have a cold?”; *regular cough*: “Do you usually cough in the morning after getting up?” or “Do you usually cough during the day, or at night?”; and *regular phlegm*: “Do you usually bring up any phlegm from your chest in the morning after getting up?” or “Do you usually bring up any phlegm from your chest during the day or at night?”.

APPENDIX TABLE 1. Classification and definition of street categories based on VECTOR25*

Street class	Definition	Street category according to VECTOR25
Side street	At least 2.8 m wide	Third-class street
	At least 4 m wide	Neighborhood street
Main street	At least 4 m wide	Second-class street
	At least 6 m wide	First-class street
	No separated lines	Major road
	Separated lines	Highway

* VECTOR25 is a digital landscape model of Switzerland and consists of nine thematic layers: road network, railway network, other traffic, hydrographic network, primary surfaces, buildings, hedges and trees, functional surfaces, and single objects. Refer to the Swiss Federal Office of Topography (<http://www.swisstopo.ch>) for more information.