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Effects of Road Traffic Noise on Prevalence of Hypertension in Men: Results of the Luebeck Blood Pressure Study

Marlis Herbold[1], Hans-Werner Hense[1], Ulrich Keil[1,2]

[1] *GSF-Medis Institut, Neuherberg bei München*
[2] *Ruhr-Universität Bochum, Abteilung für Sozialmedizin und Epidemiologie*

Introduction

Within the last decades the exposition to road traffic noise has increased immensely, and road traffic noise has become an important environmental factor with auditory and non-auditory health effects. Several epidemiological studies have investigated the influence of road traffic noise on blood pressure. Many of them reported an increase in hypertension with increasing traffic noise [1,2,3,4]. Experimental findings obtained under laboratory conditions support these findings [5,6,7]. However, there are also studies which have reported no positive associations between traffic noise and hypertension [8,9,10]. We had the opportunity to investigate the association between hypertension and exposure to road traffic noise in an epidemiological study in Luebeck.

Study Design and Methods

The Luebeck Blood Pressure Study (LBS 1984) is a cross-sectional study on a random sample of 3,100 (2,833 available) Luebeck citizens, aged 30–69 years, of whom 2,359 (83.3%) participated. Within this study each participant's housing conditions in relation to exposure to road traffic noise were assessed in a separate questionnaire. In particular, respondents were asked about the type of adjacent road and duration of residence.

Blood Pressure Measurement and Definition of Hypertension

Blood pressure (BP) was measured three times in sitting subjects after at least 25 minutes of rest; the Random Zero Sphygmomanometer (Hawksley and Sons, Ltd., [11]) and a bell stethoscope were used. All BP data were based on the 1st and 5th phases of the Korotkoff sounds and were calculated as the mean of the second and third measurements [12]. A participant was defined as actual hypertensive if the WHO-criteria were fulfilled (i.e. systolic blood pressure $\geq$ 160 mm Hg and/or diastolic blood pressure $\geq$ 95 mm Hg) and/or if current antihypertensive medication use was reported.

Exposure Variable

Exposure to road traffic noise was determined according to the self-reported type of adjacent road. The participants were asked «At which type of road is your present home located? Residential, side, main road, thoroughfare, or highway.» To avoid a misclassification-bias the following two exposure groups were formed: LOW (residential, side street) and HIGH (main street, thoroughfare, highway).

Confounders and Effect Modifiers

From previous analyses of the LBS data [12,13] it was known that age, body mass index (BMI = weight/height^2 [kg/m^2]) and alcohol consumption (average number of grams of alcohol consumed per day, for details see [13]) were potential confounders for hypertension.
Additionally, duration of residence, employment status, and years of education were considered as possible effect modifiers.

Sample Size

44 participants (22 men, 22 women) were excluded from the analysis because of missing values; therefore the following results are based on 2,315 respondents (1,046 men and 1,269 women).

Statistical Analyses

For the following statistical analyses a significance level of α=0.1 was chosen. The reason for taking this α value was that we did not want to control only the type I error α (i.e. the error one makes by falsely rejecting the null hypothesis that there is no association between exposure to road traffic noise and prevalence of hypertension), but also the type II error β (i.e. the error one makes, if one assumes that there is no association although there really exists one) and the statistical power (1-β). Table 1 shows that in our study the power arguing at the 10%-level is much higher than the power at the 5%-level.

Tab. 1. Statistical power (1-β) testing the difference of hypertension prevalence Δ = 0 for α = 0.05 and α = 0.10 in the LBS 1984, for men.

MEN	Power (1-β) α = 0.05	Power (1-β) α = 0.10
Δ = 5%	0.38	0.50
Δ = 6%	0.51	0.63
Δ = 7%	0.63	0.74
Δ = 8%	0.75	0.83
Δ = 9%	0.84	0.90

In our analyses, we were interested in achieving a high statistical power. This should protect us from missing a possible weak association between hypertension prevalence and exposure to road traffic noise.

To examine the relationship between hypertension prevalence and exposure to road traffic noise we first compared the crude prevalences of the two exposure groups.

The potential confounding variables were used for univariate stratification, and because of the homogeneity of the odds ratios of the different strata, Mantel-Haenszel odds ratios were calculated for the strata.

Then a logistic regression model was fitted by using a backward stepping procedure. Using the parameters of this model, we calculated adjusted prevalences of hypertension according to the indirect regression adjustment procedure as suggested by Wilcosky and Chambless [14]. Finally, to validate the model, we computed an overall Mantel-Haenszel odds ratio by simultaneously stratifying for all the remaining confounding variables of the model [15].

Results

Here the results for men only are presented. The association for women proved more complex and is presently still under investigation.

Regarding the two exposure groups, there were more men living in the LOW than in the HIGH exposure group, and there was an increase in hypertension prevalence from LOW to HIGH exposure (Table 2).

Stratifying by age (2 groups: men younger than 50 years / 50 years and older) yielded a higher prevalence of hypertension for older men and an increase in the prevalence of hypertension from LOW to HIGH exposure in both age groups.

Stratification by BMI (3 groups: ≤ 1. quartile = 24.4 kg/m², 1.−3. quartile, > 3. quartile = 28.5 kg/m²) produced an increase of hypertension prevalence with increasing BMI and higher prevalence of hypertension for persons living on the noisy roads in each of the BMI groups.

In each stratum of alcohol consumption (3 groups: non drinkers, < 40 g/day, ≥ 40 g/day), years of education (2 groups: < 11 years, ≥ 11 years), duration of residence (2 groups: ≤ 5 years, > 5 years), and employment status (2 groups: not fulltime, fulltime) the basic observation that the hypertension prevalence in the HIGH exposure group was always above that of the LOW exposure group was confirmed (Table 2).

Based on the crude prevalences we calculated prevalence odds ratios (POR) for HIGH versus LOW exposure and corresponding 90% confidence intervals (Table 3).

The POR for all men was 1.32. This ratio is statistically significant (α=0.10), since the corresponding confidence interval does not include the value 1.0.

Combining the data of the strata for each covariable separately by Mantel-Haenszel estimators produced rather similar odds ratios, most of which were statistically significant (α=0.10). Only the POR estimated from the three BMI strata was lower than the crude POR and failed to reach statistical significance.

On account of these results a logistic regression model was fitted by a backward stepping procedure including

Tab. 2. Numbers of participants and crude prevalence of hypertension (%) in the two exposure groups, overall and after stratification for covariables.

MEN		ROAD TRAFFIC NOISE			
		LOW exposure		HIGH exposure	
Covariables		n	Hypertension Prev. (%)	n	Hypertension Prev. (%)
	all	744	25.5	302	31.1
Age	< 50 years	407	18.7	185	25.5
	≥ 50 years	377	33.8	117	40.2
BMI	≤ 1. quartile	193	16.7	68	19.1
	1. - 3. quartile	373	24.4	151	28.5
	> 3. quartile	178	37.6	83	45.8
Alcohol	0 g/day	185	30.3	63	36.5
	< 40 g/day	458	23.1	183	28.4
	≥ 40 g/day	101	27.7	56	33.9
Education	< 11 years	389	28.0	161	33.5
	≥ 11 years	355	22.8	141	28.4
Duration of residence	< 5 years	212	18.9	99	20.2
	≥ 5 years	532	28.2	203	36.4
Employment status	not fulltime	201	35.8	82	37.8
	fulltime	543	21.7	220	28.6

Tab. 3. Overall and Mantel-Haenszel prevalence odds ratios (POR/POR_{MH}) with 90% confidence intervals (CI) obtained after stratification for covariables.

MEN		
	POR	90% CI
overall	1.32	1.03-1.69
Covariable	POR_{MH}	90% CI
Age	1.40	1.09 - 1.80
BMI	1.28	0.99 - 1.64
Alcohol	1.32	1.03 - 1.70
Education	1.32	1.03 - 1.68
Duration of residence	1.36	1.06 - 1.74
Employment status	1.32	1.03 - 1.70

Tab. 4. Logistic regression model for hypertension as dependent variable. Estimated regression coefficients and p-value for the test of $\beta = 0$.

MEN	Prevalence of Hypertension	
Variable	β	p-value
Intercept	-0.99	< 0.001
Road Traffic Noise [HIGH]	0.28	0.075
Age [(x-50)/10]	0.36	< 0.001
BMI [(x-26)/10)]	1.28	< 0.001
Alcohol [0< x <40 g]	-0.32	0.027

the variables age, BMI (both continuously and centered around the mean), alcohol consumption, years of education, duration of residence, and employment status as possible confounders and effect modifiers of the exposure variable road traffic noise.

The stepping procedure ended with a model (Table 4) that still contained the variables age and BMI (both as continuous variables) and alcohol consumption.

The model indicated a significant positive effect of road traffic noise on the prevalence of hypertension in men (regression coefficient β=0.28, p=0.075).

Using the parameters of this final logistic regression model we calculated adjusted prevalences of hypertension for the two exposure groups by indirect regression adjustment [14]. Comparison of these adjusted hypertension prevalences with the crude prevalences showed (Table 5) that they were nearly identical and that the increase in prevalence of hypertension from LOW to HIGH exposure remained statistically significant also after adjustment (α=0.10).

A prevalence odds ratio adjusted for the coefficients of the logistic regression model was computed (Table 6); it was nearly the same as the original odds ratio of the crude prevalences and also statistically significantly greater than 1.0 (α=0.10).

To validate this model [15] we simultaneously stratified for age (2 groups), BMI (3 groups) and alcohol consumption (3 groups). For all these 18 strata we calculated prevalence odds ratios and a weighted overall-effect estimator according to Mantel-Haenszel (Table 6). The resulting odds ratio was again very close to the odds ratio calculated with the logistic regression model.

Discussion

We found a higher prevalence of actual hypertension in men residing in noisier streets. As the location of a person's home is determined by many factors, in particular social ones, it may be assumed that living in noisier streets is an indicator of lower social standing

Tab. 5. Crude and adjusted prevalence of hypertension in the two exposure groups with difference Δ and p-value for test of $\alpha = 0$.

MEN	ROAD TRAFFIC NOISE LOW exposure	HIGH exposure	Δ	p-value
crude prevalence of hypertension	25.5 %	31.1 %	5.6 %	0.066
adjusted prevalence of hypertension	25.6 %	30.9 %	5.3 %	0.086

Tab. 6. Prevalence odds ratios (POR) with 90% confidence intervals (CI) obtained after logistic regression modelling and multivariate stratification.

MEN Method	POR	90% CI
adjusted by logistic regression model	1.32	1.02 - 1.71
Mantel-Haenszel estimator after stratification by BMI, AGE and ALCOHOL	1.38	1.07 - 1.78

and that the described association reflects only the well-known higher frequency of hypertension in lower social classes [16].

However, we did not find any significant differences between the two groups of men with regard to years of education, employment status, duration of residence, antihypertensive medication, or alcohol consumption. In addition, stratification by these variables showed that the increased prevalence of hypertension is always maintained. Logistic regression modelling and the calculation of pooled estimates for the overall prevalence odds ratio confirmed our contention that social confounders are an unlikely explanation for the observed association.

Self-selection of aware hypertensives or men with increased sympathetic tone into the noisier road groups could be an alternative explanation for our findings. However, the proportion of aware hypertensives was almost equal in each group; the mean heart rates – as surrogate measure for sympathetic tone – were 75.3 (HIGH) and 74.2 bpm (LOW), respectively, ($p=0.145$); the phrasing of our question for type of road was such that density of traffic flow rather than perceived annoyance or interference were determinants of the road classification. A bias due to self-selection is thus unlikely.

It is noteworthy that the statistical significance level applied throughout our analyses was at $\alpha=0.10$ and thus above the common 5% level. This approach was chosen in order to increase the statistical power of the investigation to detect small differences between the two exposure groups (Table 1).

On the other hand, one has to be aware of the increased probability of falsely rejecting the 'no-effect-hypothesis'. We feel, however, that it is a reasonable procedure to accept a relatively large type I error when presumably weak effects are under study and when the exposure classification is not very specific.

Several epidemiologic studies investigated the association of hypertension prevalence and exposure to road traffic noise. To our knowledge, no other study was done on this subject in a random sample of the adult population of a city. The only comparable study, the Caerphilly-Study in Wales, has to date only reported analyses of noise effect on systolic and diastolic BP means, with correlational as well as analyses of variances [3]. Their findings point in a similar direction as our study.

The results of the Luebeck Blood Pressure Study suggest that living in streets with high traffic density may in men increase the occurrence of hypertension beyond the magnitude explained by other factors. This should draw our attention to the role of environmental exposures in the development of cardiovascular disease.

Summary

Within the Luebeck Blood Pressure Study – a cross-sectional study of 2,315 Luebeck citizens, aged 30–69 years, response 83.3% – the association between blood pressure and exposure to road traffic noise at home was investigated. Road traffic noise was grouped as HIGH and LOW exposure, hypertension was defined as either SBP ≥ 160 mm Hg and/or DBP ≥ 95 mm Hg and/or on antihypertensive medication. A comparison of the crude prevalence of hypertension showed an increase of prevalence for men from 25.5% in the LOW to 31.1% in the HIGH exposure group (odds ratio: 1.32; 90% CI: 1.03–1.69), which was statistically significant at the α-level of 0.1. After univariate analyses the variables age, BMI, alcohol consumption, years of education, duration of residence, and employment status were considered as possible confounders or effect modifiers. A logistic regression model was fitted by using a backward stepping procedure. Prevalences were adjusted by using this logistic regression model. Differences between adjusted prevalences in LOW and HIGH exposure groups were similar to the crude differences. The odds ratio computed by the coefficients of this model was also similar to the corresponding odds ratio above. To validate the model we simultaneously stratified the remaining variable of the final model and combined the resulting odds ratios by Mantel-Haenszel. The results were again similar.

According to the results of this study a positive association between exposure to road traffic noise and prevalence of hypertension in men is probable.

Résumé

L'effet du bruit de la circulation sur la pression artérielle dans l'étude de Luebeck

Dans le cadre de l'étude de Luebeck sur la pression artérielle – une étude transversale sur 2315 résidents âgés de 30 à 69 ans (taux de participation de 83.3%) – des questions portant sur l'exposition au bruit de circulation au domicile et sur la pression artérielle ont été posées. Le bruit de la circulation a été classé en exposition forte (BRUYANT) et basse (CALME); l'hypertension a été définie avec une valeur systolique ≥ 160 mm Hg et/ou une valeur diastolique ≥ 95 mm Hg. et/ou traitement médicamenteux de l'hypertension. Une comparaison des prévalences brutes de l'hypertension artérielle avec la prévalence de l'hypertension artérielle a montré une relation significative (25.5% dans le groupe CALME, 31.1% dans le groupe d'exposition BRUYANT; odds ratio: 1.32; 90% CI: 1.03–1.69). A partir de ces résultats, les variables âge, indice de masse corporelle, consommation d'alcool, niveau d'instruction, durée de résidence et profession ont été considérées comme facteurs confondants dans un modèle de régression logistique (backward stepping), avec la prévalence de l'hypertension artérielle comme variable dépendante. Ce modèle permet de calculer des prévalences ajustées. Des différences entre les groupes d'exposition au bruit sont mises en évidence par ce modèle avec un odds ratio ajusté presque identique à celui sans ajustement. La validité du modèle a été vérifiée par une stratification simultanée, considérant toutes les variables et les odds ratios de tous les sous-groupes selon le test de Mantel-Haenszel, ce qui a conduit à nouveau à des résultats analogues. Cette étude permet donc de supposer qu'une relation directe existe entre l'exposition au bruit de circulation sur le lieu de domicile et la pression artérielle.

Zusammenfassung

Auswirkungen des Straßenverkehrslärms auf die Hypertonieprävalenz

Im Rahmen der Lübecker Blutdruckstudie – einer Querschnittsstudie an 2315 30–69jährigen Lübecker Bürgern (Beteiligung 83.3%) – wurden auch Fragen zum Zusammenhang zwischen Blutdruck und Straßenverkehrslärmexposition am Wohnort untersucht. Straßenverkehrslärm wurde in hohe (LAUT) und niedrige (LEISE) Exposition eingeteilt. Hypertonie wurde als Systole ≥ 160 mm Hg und/oder Diastole ≥ 95 mm Hg und/oder Einnahme von Antihypertensiva definiert. Ein Vergleich der rohen Hypertonieprävalenzen zeigte bei Männern einen Anstieg der Hypertonieprävalenz von 25.5% in der LEISEn auf 31.1% in der LAUTen Expositionsgruppe (Odds Ratio: 1.32; 90% CI: 1.03–1.69), der statistisch signifikant ist für $\alpha=0.1$. Anhand der Ergebnisse univariater Analysen wurden die Variablen Alter, BMI, Alkoholkonsum, Ausbildungsjahre, Wohndauer und Berufstätigkeit als mögliche Confounder oder Effect Modifier berücksichtigt und schrittweise (backward stepping) ein logistisches Regressionsmodell für die Hypertonieprävalenz ange-

paßt. Mit den Parametern dieses Modells wurden adjustierte Prävalenzen berechnet. Auch hier zeigten sich ähnliche Unterschiede zwischen LEISEr und LAUTer Expositionsgruppe wie bei den rohen Prävalenzen und auch die anhand dieses Modells berechnete Odds Ratio der adjustierten Prävalenzen war fast identisch mit der rohen Odds Ratio. Um die Validität des Modells zu überprüfen, wurde simultan nach allen Variablen des Modells stratifiziert und die Odds Ratios aller dieser Strata nach Mantel-Haenszel zusammengefaßt. Dies führte wiederum zu ähnlichen Resultaten. Ausgehend von den Ergebnissen dieser Studie ist somit zu vermuten, daß eine positive Beziehung zwischen Straßenverkehrslärmexposition am Wohnort und Hypertonieprävalenz existiert.

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Address for correspondence:

Marlis Herbold, Dipl.-Math.
GSF Medis-Institut
Ingolstädter Landstrasse 1
D-8042 Neuherberg