TRAFFIC NOISE AND MYOCARDIAL INFARCTION
RESULTS FROM THE NAROMI STUDY (NOISE AND RISK OF MYOCARDIAL INFARCTION)

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Introduction Epidemiological studies on the relationship between transportation noise and ischemic heart disease suggest a higher risk of myocardial infarction in subjects exposed to high levels of traffic noise [1]. Although the findings in these studies seem to be reasonably consistent, individual study results often lack significance due to the low statistical power of the study. Expert groups rated the evidence of the association in between "limited" and "sufficient" [2]. A meta-analysis that was undertaken suggests a dose-response relationship for the suspected association [3].

A previous population-based case-control study carried out in the former western part of the city of Berlin, revealed an estimate of the relative risk for myocardial infarction of OR=1.3 (95% confidence interval: 0.9-2.0) in males, who had lived for at least 15 years in streets with average A-weighted sound levels of more than 70 dB(A) during the day compared to subjects who lived in streets with sound levels up to 60 dB(A) [4]. The present study is a replica of the previous one, using the same test hypothesis. It takes a larger sample size and uses improved methods of exposure assessment, and a larger set of potentially confounding variables are taken into account in the statistical analyses. It is a hospital-based case-control study covering the entire city of Berlin.

Methods To determine the potential risk of noise for the incidence of myocardial infarction (MI), consecutive patients admitted to 32 major hospitals in Berlin with confirmed diagnosis of acute MI and reanimated survivors of sudden cardiac death were enrolled over a prospective period of 3 years from 1998 to 2001. The diagnostic criteria followed the WHO definitions, including ischemic changes in the ECG, clinical symptoms and enzymatic changes. Hospital controls were matched according to gender, age (5 yr categories) and hospital. Because of the lower incidence rate of MI in women, a case:control ratio of 1:1 for men and 1:2 for women was taken, so increasing the statistical power. It was presumed that the diagnoses of control patients admitted to the same hospitals for accidents or surgical procedures were not related with noise. These diagnoses included hernia, goitre, colon or rectum problems and accidents at home, at work, at leisure and from traffic.

The total number of 4115 study participants (age: 20-69 yrs) was made up of 3054 males (mean age 56.1 yrs, SD = 8.5) and 1061 females (mean age 57.7 yrs, SD = 8.7). Standardized interviews were conducted during the hospital stay, after the subjects were moved from the intensive care wards, to the peripheral wards to assess information about the home environment, socio-demographic and potentially confounding factors. These included: family history of MI ("yes/no"), smoking ("present smoker/former smoker/non-smoker"), school educational level ("A-level/below A-level"), marital status ("single/with partner"), employment status ("unemployed/not in work for other reasons/employed"), working hours (">40hr per

week/others”), shift work (“yes/no”), second job or activity (“yes/no”) and Weinstein noise sensitivity (continuous scale ranging from 1 to 6). Clinical diagnoses regarding the prevalence of diabetes (“yes/no”), hypertension (“yes/no”), hyperlipemia (“yes/no”) and body mass index (“no data/>30/>25-30/≤25 kg/m^2”) were taken from records of the clinics. Adjustments in the statistical analyses were made with respect to the categorizations given in brackets. Due to possibly incomplete assessment in controls, hyperlipemia was considered only in sensitivity analyses, which did not affect the results considerably. The 10 years work noise exposure (sound level) was determined according to ISO 9921/1 assessing vocal effort for speech communication and according to catalogues for workplaces and machines, accounting for the use of ear protection. More details will be given elsewhere. For the present analyses one indicator of occupational noise exposure (“no data/no job/≤55/>55-70/>70-85/>85 dB(A), corrected for use of ear protection”) was used to control for possible confounding. Replacing it with other work noise indicators did not considerably affect the results of the traffic noise level-related analyses.

The objective traffic noise exposure (sound level) of the subjects was assessed using noise maps of the city authorities and standardised questionnaires. The traffic noise levels (average A-weighted sound pressure level) as determined from noise maps were calculated with reference to the most affected facades of the dwellings for day (6-22 h) and night (22-6 h). The noise maps were established in accordance with German standards for road and rail traffic (RLS90, Schall09) and accounted for reflections from buildings opposite [5]. All major streets with more than approx. 6000 vehicles per day were assessed by the traffic authorities, and exact sound immission levels were calculated. Streets with less traffic volume were categorised as "quiet". No exact sound levels can be given for these streets. However, the cut-off criterion refers to average A-weighted sound levels during the day ($L_{6\text{-}22hr}$) of approx. 60 dB(A) and approx 50 dB(A) during the night ($L_{22\text{-}6hr}$) at a distance of 25 m from the streets (max. speed 50 km/h, 5% heavy vehicles). This group served as the reference group in the main statistical analyses according to the test hypothesis and for comparison with the previous study.

All individual’s houses were categorized in 5 dB(A)-categories according to the sound levels given in the traffic noise map. In the first step this was done with reference to the home address (in most cases the street closest to the buildings). In the second step, all addresses were checked for noise from streets other than the home address. Using high-resolution GIS information (digitalized topographic maps, scale 1:500), the distances to all streets of which exact sound levels were given in the noise map were measured for each house where subjects lived. If the subject’s houses were within relevant distances to such streets (i.e. according to physical rules of sound propagation), and not completely shielded by sound barriers from other houses, exact sound levels were calculated with respect to the nearest facade of the subjects’ houses. When this sound level was higher than the one for the street of the address, the subjects were re-allocated into the respective sound level category. Otherwise, the subjects remained in their initial category. All noise calculations were made separately with respect to the front of the house (facing the street of the address) and to the back of the house.

To account for transportation noise other than from the streets, dichotomous variables were assessed, so that subjects who lived within the 60 dB(A) contours around airports or near railway lines could be noted. The calculations were made according to the German aircraft noise regulations (exception: equivalence parameter "q=3" was considered), the train noise

module of the Berlin noise map, and the measured distance of houses from railway lines. The two variables were considered as potential confounders in the statistical analyses.
The subjective noise exposure (annoyance) was assessed using a standardized questionnaire. Personal interviews were carried out in the hospitals. Environmental noise annoyance was determined using a 5 point scale of which the anchor points were verbalised ("Considering the last years, how much are you disturbed by x-noise at home"; 1= not disturbed at all, 5 = very disturbed). Eight noise sources around and in the subject's homes were considered. These included: road traffic noise, aircraft noise, railway noise (including tram), noise from construction works, commercial noise (including noise from industries), impact noise, indoor noise and other outdoor noises. The items were presented in two lists referring to disturbances during the day and the night. To control for annoyance from occupational noise, an indicator variable was used ("no data/no job during past 10 years/low/fairly low/fairly high/high annoyance"). It was based on information, which was taken from the noise questionnaire referring to noise from the outside of the working room, from own machines or appliances and noise from machines or appliances used by colleagues.

Conditional logistic regression analyses (LogXAct 4.02) were carried out to estimate relative risks (matched analyses), and to adjust the results for a set of potential confounding factors. Non-parametric regression coefficients (SPSS 9.0) were calculated to assess associations between the determinants of noise exposure.

Results Table 1 gives the distribution of traffic noise levels during day in the overall sample. It refers to the highest sound level measured during daytime at any outside wall of the subjects' houses. Since non-categorized day and night sound levels were highly correlated (Spearman r = 0.97), only the results referring to the sound level during day are given here. In future analyses, a distinction will be made between the exposure of the living room and the bedroom. Approx. 16% of the subject's houses were exposed to sound levels of more than 65 dB(A) during the day. The result reflects the noise distribution in a random sample of the German population [6].

Table 1 Association between traffic noise level and MI-incidence (main analyses)

Sound level, day [dB(A)] Relative MI risk [OR ± 95% CI]	≤60 n=2990 (72.6%)	>60-65 n=472 (11.5%)	>65-70 n=430 (10.4%)	>70 n=223 (5.3%)
Females	1	1.14 (0.70-1.85)	0.93 (0.57-1.52)	0.66 (0.32-1.35)
Males	1	1.01 (0.77-1.31)	1.13 (0.86-1.49)	1.27 (0.88-1.84)

Table 1 also gives (for all the control variables mentioned above) the adjusted estimates of the relative risk (odds ratios) of myocardial infarction (MI) and 95%-confidence intervals (95% CI) for males and females in each traffic noise category. A slight increase in risk was found in males with increasing sound level. The relative risk of OR=1.3 (95% CI: 0.9-1.8) found for men in the highest noise category (>70 dB(A)) compared to the lowest (≤60 dB(A)) was not significant. In females the opposite trend was found. The relative risk for those in the highest category was 0.7 (95% CI: 0.3-1.4) and was also not significant.

A puzzling result was found while carrying out the statistical analyses. Within the reference group two subgroups were identified. Subgroup 1 consisted of subjects who lived in side streets, that were not in relevant distance to busy streets, or were completely shielded by sound barriers from these streets. No exact sound levels below the estimate of $L_{Day} \leq 60$ dB(A) were given here. Subgroup 2 consisted of subjects who lived in relevant distances to busy streets so that sound levels could have been higher, but exact sound level calculations with respect to these streets revealed that $L_{Day} \leq 60$ dB(A) was assured. Table 2 gives the odds ratios of MI incidence with reference once to subgroup 1 and once to subgroup 2. Surprisingly, a significantly lower MI risk was found in both sexes in subgroup 2, when subgroup 1 served as the reference. In the opposite case, when subgroup 2 served as the reference, male subjects from all other exposure groups and females from subgroup 1 and subgroup ">60-65" showed significantly higher MI risks.

Table 2 Association between traffic noise level and MI-incidence (sub-analyses)

Sound level, day [dB(A)] Relative MI risk [OR ± 95% CI]	≤60 subgroup 1 * n=2437	≤60 subgroup 2 ** n=553	>60-65 n=472	>65-70 n=430	>70 n=223
Females	1	0.45 (0.27-0.76)	1.03 (0.63-1.68)	0.83 (0.51-1.37)	0.58 (0.28-1.20)
Males	1	0.67 (0.52-0.85)	0.94 (0.72-1.23)	1.03 (0.77-1.37)	1.16 (0.80-1.69)
Females	2.21 (1.31-3.72)	1	2.27 (1.16-4.45)	1.84 (0.94-3.61)	1.29 (0.56-2.99)
Males	1.50 (1.18-1.91)	1	1.41 (1.01-1.97)	1.54 (1.10-2.16)	1.74 (1.15-2.64)

* Subject's houses not in relevant distance to a busy street or completely shielded by sound barriers.
** Subject's houses in relevant distance to a busy street but calculations of the sound level revealed that 60 dB(A) was not exceeded.

Table 3 gives the distribution of source-specific annoyance ratings for day and night. 13% were highly annoyed by road traffic noise during the day and 8% by road traffic noise during the night. The picture was similar to that found for all of Germany [6]. Only annoyance due to aircraft noise was higher because Berlin has an international airport.

Table 4 shows the associations between noise annoyance and MI incidence. Separate models were calculated with respect to disturbances during the day and night. To handle all the eight annoyance variables simultaneously, they were treated as continuous variables in the models. The odds ratios give an estimate of the relative risk per unit of the 5-point scale. All sound level-related variables were excluded from the analyses as well as noise sensitivity for reasons of collinearity between variables. However, annoyance from noise at work was considered. Road traffic noise annoyance at night (OR=1.10; 95% CI: 1.01-1.20) and aircraft noise annoyance at night (OR=1.28; 95% CI: 1.01-1.63) were significantly associated with an increase in MI risk.

Discussion In the present epidemiological study, the findings from an earlier study using largely the same methods were confirmed. Male subjects that lived in streets with average A-weighted sound levels during the day of more than 70 dB(A) showed a slight increase in risk of

myocardial infarction compared with those that lived in streets with less/equal 60 dB(A). The odds ratio of OR=1.3 was statistically not significant but of the same magnitude as in the earlier study. With increasing traffic noise level an increase in risk was found. In females an opposite trend of a decreasing risk in higher traffic noise exposed subjects was found, which was also not significant. More detailed analyses of the data are in progress. Meta analyses may be a tool to combine the data of the earlier study with the present one to increase the statistical power.

Table 3 Distribution of annoyance ratings due to different noise sources

Annoyance during day [5-point scale]	1	2	3	4+5
Road traffic noise [%]	45.5	24.5	16.8	13.2
Aircraft noise [%]	63.0	21.0	8.6	7.4
Rail noise [%]	83.9	9.2	3.9	3.0
Industrial noise [%]	90.1	4.5	2.9	2.5
Construction noise [%]	73.1	9.7	7.3	9.9
Other outdoor noise [%]	68.9	17.7	6.7	6.7
Impact noise indoors [%]	74.1	12.6	6.5	6.8
Other indoor noise [%]	72.3	15.1	6.6	6.0
Annoyance during night [5-point scale]	1	2	3	4+5
Road traffic noise [%]	73.6	11.6	7.3	7.5
Aircraft noise [%]	88.2	6.6	2.6	2.6
Rail noise [%]	90.9	5.1	2.3	1.7
Industrial noise [%]	95.2	1.8	1.1	1.9
Construction noise [%]	96.9	1.2	0.8	1.1
Other outdoor noise [%]	84.3	8.4	3.9	3.4
Impact noise indoors [%]	88.7	5.4	2.9	3.0
Other indoor noise [%]	83.8	9.4	3.8	3.0

Table 4: Association between noise annoyance and MI-incidence

	Relative MI risk [OR ± 95% CI]			
Annoyance [5-point scale]	Females day	Females night	Males day	Males night
Road traffic noise	1.03 (0.90-1.18)	0.98 (0.84-1.14)	1.04 (0.97-1.12)	**1.10 (1.01-1.20)**
Aircraft noise	1.13 (0.97-1.32)	**1.28 (1.01-1.63)**	1.01 (0.93-1.10)	1.05 (0.93-1.19)
Rail noise	0.96 (0.78-1.18)	0.94 (0.71-1.24)	0.92 (0.82-1.04)	0.99 (0.85-1.15)
Industrial noise	1.11 (0.89-1.39)	1.02 (0.76-1.36)	1.06 (0.93-1.21)	0.91 (0.77-1.08)
Construction noise	1.05 (0.93-1.20)	1.17 (0.87-1.57)	1.08 (1.00-1.17)	1.10 (0.87-1.39)
Other outdoor noise	0.99 (0.85-1.15)	1.00 (0.82-1.22)	0.96 (0.88-1.05)	0.96 (0.86-1.07)
Impact noise indoors	0.94 (0.79-1.11)	0.95 (0.75-1.20)	1.04 (0.95-1.14)	1.02 (0.90-1.16)
Other indoor noise	1.03 (0.88-1.21)	1.09 (0.89-1.33)	0.92 (0.84-1.02)	0.99 (0.87-1.12)

No explanation can be given at the moment for the strong protective effect found in a subgroup of the reference group. It may be attractive to consider only this group (subgroup 2) as a reference group in the analyses. Subjects from most of the other noise categories would then be significant at higher risk, including subgroup 1. Calculated sound levels (day) for subgroup 2 ranged between >55 to 60 dB(A). These sound levels referred mostly to busy streets in the distance, but not to the home address (sides street) of the subjects' houses. No exact sound levels can be given for subgroup 2, but busy streets were not within relevant distances to these

subjects' houses. In both cases, side streets were classified as ≤60 dB(A) due to low traffic volume. From common measurement experience it is known that sound levels in such streets range between 50 to 60 dB(A) during day. Figure 1 shows the association between traffic noise level and annoyance ratings. Annoyance due to traffic noise showed an increase with increasing sound level. Subjects from subgroup 1 were least annoyed followed by subgroup 2. This is in accordance with the repeatedly found monotonous trends between sound level and annoyance in social surveys [7]. The finding shows no reason to believe that subjects in subgroup 1, on average, were exposed to higher traffic noise than those in subgroup 2. The conclusion that only in males a slight increase in MI risk was found with increasing traffic noise level, and not in females, is supported by the fact, that only in males a positive relationship to noise annoyance due to road traffic noise was found, and not in females.

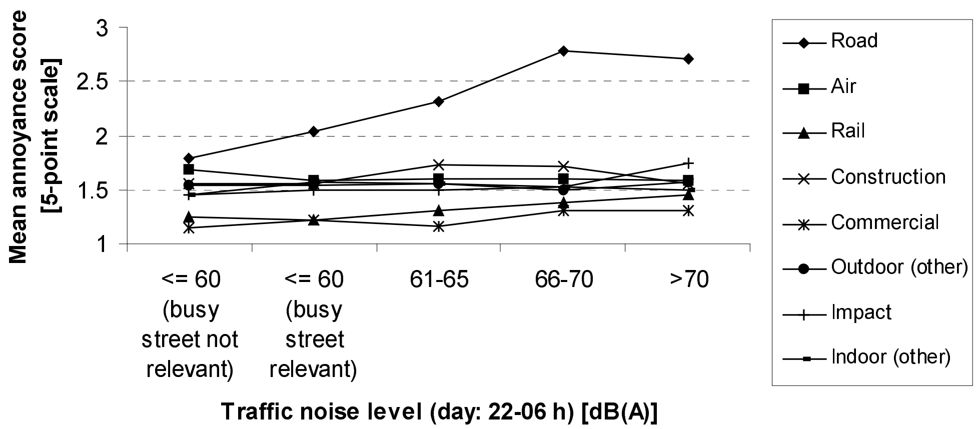

Figure. 1: Association between traffic noise level and annoyance ratings due to different noise sources

Keywords: traffic noise, noise annoyance, myocardial infarction, case-control study

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