Soz.-Präventivmed. 42 (1997) 216–222
0303-8408/97/040216-07 $ 1.50 + 0.20/0

Hartmut Ising, Wolfgang Babisch, Barbara Kruppa, Alfred Lindthammer, Daniel Wiens

Umweltbundesamt, Institut für Wasser-, Boden- und Lufthygiene, Berlin

Subjective work noise: A major risk factor in myocardial infarction

Summary

The relationship between subjective work noise exposure and the risk of myocardial infarction (MI) was assessed in a population based case-control study. 395 MI patients (31–65 years) were compared to 2148 controls from a random population sample with the same age/sex distribution. The relative risk (RR) for MI – adjusted for control variables (smoking, age, social status, etc.) – was found to increase significantly and steadily with noise category. Subjective work noise exposure was the second greatest risk factor for MI after smoking. Possible bias due to overreporting of subjective noise exposure is discussed. Interdisciplinary studies on the relationship between cardiovascular diseases and work-related stressors including subjective and objective noise assessment are needed to quantify the risk of MI due to work noise.

Introduction

There is general agreement that noise acts as a non-specific stressor[1] and that its non-auditive effects, i.e. its effects on the organism as a whole, are essentially stress reactions[2–4]. Stress reactions are determined not only by external factors, but first and foremost by the internal assessment of external load[5,6]. This is especially true of noise as a stressor. Non-auditive (i.e. vegetative) noise effects are more closely correlated to noise-induced disturbance than to the noise level[7]. Vegetative noise effects, such as alterations in peripheral blood circulation and in galvanic skin resistance, do not in themselves indicate a pathological health condition. Other effects of acute noise-induced stress, such as changes in serum concentrations of cholesterol and triglycerides and in blood pressure, point to an increased risk of myocardial infarction (MI)[8–10]. Furthermore, in two cross-sectional epidemiological studies several risk factors in MI showed a non-significant increase in the group with maximum traffic noise level[11,12]. In a work noise study, cholesterol and triglycerides were significantly increased in men working under noise exposure >85 dB (A)[13].
The existing literature about long-term health effects of work noise is inconclusive[14]. The reasons for this are mainly of a methodological nature and have been discussed by Thompson[15,16]. Recent epidemiological studies investigating circulatory diseases, particularly MI, in relation to road traffic noise levels suffer from low statistical power due to the small numbers of highly exposed subjects. This is especially true of the Caerphilly and Speedwell prospective heart disease studies[11], which showed a non-significant increase in the risk of MI in relation to road traffic noise levels, and of the Berlin population based case-control study, in which a small increase of borderline significance in the risk of MI in the most highly exposed group was found[17].
In order to study the relationship between subjective work noise as a stressor and myocardial infarction, we reanalysed the data of the Berlin traffic noise study using subjective work noise load as the exposure variable and traffic noise as one of the control variables.

Method

The Berlin traffic noise study is a population based case-control study. Men aged 31 to 70 years who were treated for acute MI (ICD 410) in the major Berlin hospitals were considered as "cases". They

were interviewed by a physician and questioned about potential control variables (age, social class, education, employment status, shift work, smoking habits, body mass index, family status, residential area) as well as about work noise (see below) and their home address. The study area itself was clearly defined by the island situation of Berlin (West) before 1990. All surviving patients with MI in 17 (out of 24) major hospitals with intensive care units were identified in the course of one year. A total of 693 subjects co-operated and satisfied the inclusion criteria, yielding a participation rate of 91%. Because some hospitals were not included, 80–85% of the source population ultimately co-operated (see [18] for details).
For controls, a random sample of the source population with a similar age distribution to the cases was drawn by the local registration office. Of the 6002 men identified, 3865 responded by returning a completed questionnaire, yielding a participation rate of 64% (68% of all men who received the questionnaire). Obvious hints at the aim of the study (in particular noise) were avoided, both in the questionnaires and in interviews with the patients. The most probable effect of the 36% non-responders seemed to be a distortion of social class in the control group. Therefore we compared the social class data of the source population with the data of our control group using officials census data. The biggest difference was between the percentage of workers in the source population (37%) and in the control group (29%). The effect of this distortion of social class distribution was taken into consideration when estimating the population attributable risk percentage.
All subjects were classified with respect to individual residential road traffic noise levels using road traffic noise maps produced by the Berlin city authorities. For the work noise analysis, the age range was limited to 65 years (normal upper working age limit). Persons in early retirement and unemployed persons were excluded from the analysis. In the age range from 31–65 years 583 MI cases participated, 188 (32%) of whom were unemployed. This yielded a total of 395 employed men in the MI group. In the control group 3228 men aged 31–65 years completed the questionnaire. 1080 (34%) of them were unemployed so that for the work noise analysis the control group consisted of 2148 employed men. The age distributions of cases and controls are shown in Table 1.
Subjective work noise was quantified by questionnaire. The instruction for the subjects was: From the following noise sources please select that which best describes roughly how loud it is at your workplace: 1) refrigerator, 2) typewriter, 3) electric lawnmower, 4) electric drill, 5) pneumatic drill.
The correlation between subjective and objective noise assessment was investigated in a small additional test sample of 80 men. While the questionnaire was being filled in, a technician measured noise at the workplace as a one-minute mean level (Norsonic Type 110).
Logistic regression analyses were performed using the PC-Windows 6.0 version of the SPSS statistical software package, and test-based confidence limits of relative risks were calculated.

Results

The distribution of cases and controls with respect to subjective work noise categories is shown in Table 2.
In Figure 1, the results of the subjective work noise assessment are compared with the noise level data. The medians are given as well as

Age	31–40	41–45	46–50	51–55	56–60	61–65 years
MI	42 (10.6%)	43 (10.9%)	79 (20%)	115 (29.1%)	95 (24.1%)	21 (5.3%)
Controls	161 (7.5%)	233 (10.8%)	386 (18.6%)	752 (35.0%)	464 (21.4%)	152 (7.1%)

Table 1. *Age distribution of cases and controls.*

Work noise category	1 + 2	3	4	5
MI incidences	149 (37.7%)	71 (18.0%)	88 (22.3%)	87 (22.0%)
Controls	1221 (56.8%)	397 (18.5%)	358 (16.7%)	172 (8.0%)

Table 2. *Work noise distribution of cases and controls in the Berlin work noise study.*

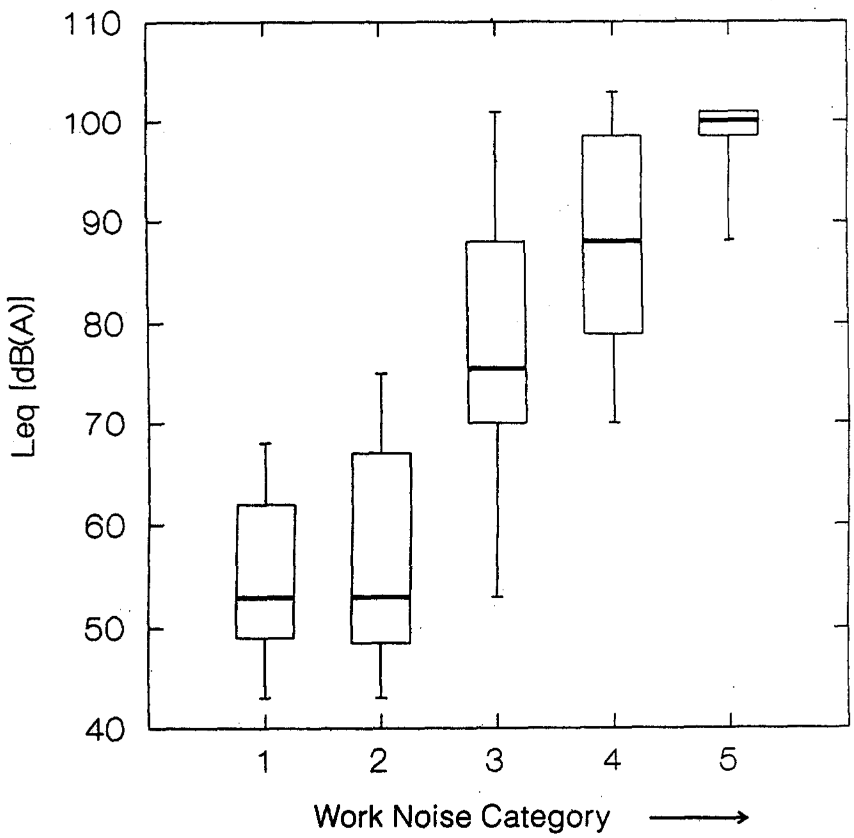

Figure 1. *Work noise level (measured as one-minute mean level) in relation to the subjective work noise category (1: refrigerator, 2: typewriter, n (1 + 2) = 27; 3: electric lawn-mower, n (3) = 22; 4: electric drill, n (4) = 16; 5: pneumatic drill, n (5) = 15). The median, 25 and 75 percentiles and extreme values of the noise level distribution are shown.*

	MI	Controls
Body mass index (> 27.7 kg/m^2)	30.7 %	23.3 %
Social class (low)	35.2 %	27.3 %
Education (college degree)	14.7 %	28.0 %
Marital status (divorced + widowed)	16.2 %	8.4 %
Residential area (outskirts)	38.7 %	44.9 %
Shift work (yes)	14.2 %	14.4 %
Current smoking (yes)	68.1 %	38.2 %
Work noise (categories 3 + 4 + 5)	62.3 %	43.2 %

Table 3. *Description of cases and controls concerning control variables and work noise.*

the 25 and the 75 percentiles and the extreme values of the work noise levels in relation to the subjective work noise categories. Since the medians of the noise levels proved to be identical in the two lower categories (1: refrigerator, and 2: typewriter) and the relative risks of MI were almost identical, these categories were pooled and used as a reference in assessing the relative risks (RR) of MI in relation to subjective noise. In the higher work noise categories (3: electric lawnmower, 4: electric drill, 5: pneumatic drill) the median of the work noise level increased steadily. The variance of sound pressure levels within the subjective noise categories amounted to values between ±6 and ±24 dB. The rank correlation coefficient between noise categories and Leq was r = 0.84.

In Table 3, the cases and controls are compared in relation to control variables and the sum of the work noise categories 3 + 4 + 5. The relative risks of MI were adjusted with respect to the above-mentioned control variables and are listed in relation to the work noise categories together with the 95% confidence intervals in Table 4. The risk of MI increased significantly and steadily with subjective work noise exposure.

Stratification of the results into three age groups shows that in the youngest age group the relative risk of MI increased more conspicuously with subjective work noise than in older age groups (Fig. 2).

Additionally we studied the interaction of smoking, noise and age. For this purpose the MI cases and controls were divided into two age groups (up to 50 years and 51–65 years) and two noise groups (categories 1 + 2 and categories 3 + 4 + 5). The other control variables were included in the model. The results of the full model including interaction terms are given in Tab. 5. The only borderline significant interaction was that between age and noise at 0.46 ($p = 0.058$), indicating that men in the age group of 51–65 years exposed to category 3 subjective work noise or more carried a decreased relative risk as compared to younger men.

Since the control group for the Berlin work noise study was more or less a random population sample it was possible to approximate a population attributable risk percentage based on subjective noise

Noise category		RR for MI (ICD 410)	
1 + 2	refrigerator/typewriter	1.0	(ref. level)
3	electric lawn-mower	1.4	(1.03/1.97)
4	electric drill	2.0	(1.45/2.74)
5	pneumatic drill	3.8	(2.68/5.44)

Table 4. *Relationship between work noise and relative risks (RR) of MI adjusted for co-variates (smoking, body mass index, age, social class, education, marital status, shift work, housing area), 95% confidence intervals are given in brackets.*

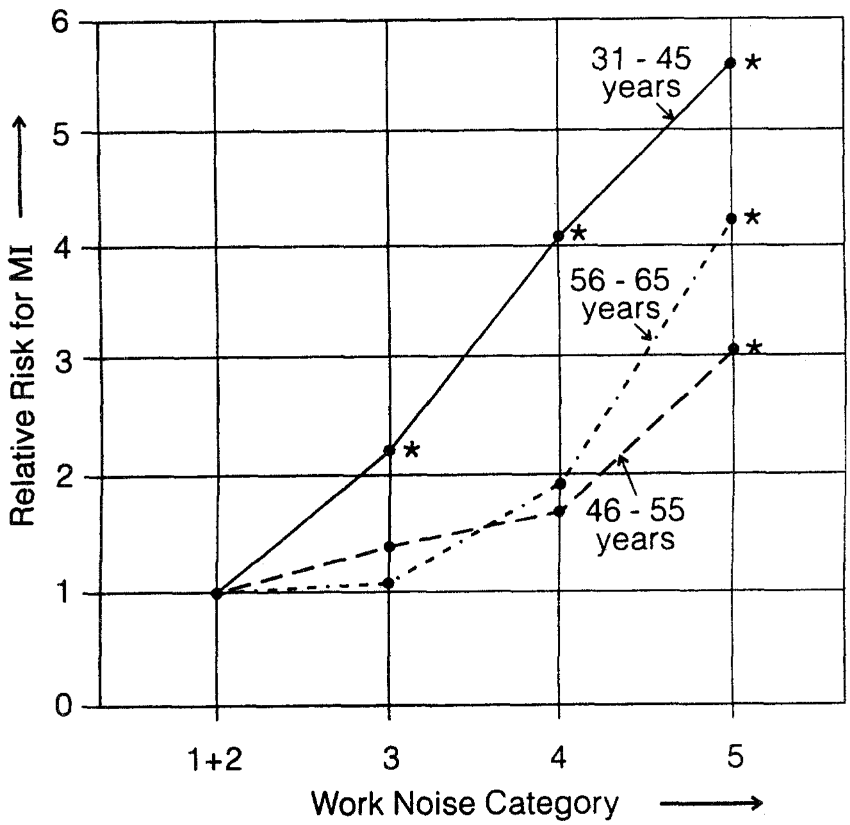

Figure 2. *Relative risk (RR) of MI in men (subdivided into 3 age groups) by work noise category. Work noise was assessed by subjective comparison with typical noise sources (1 + 2: refrigerator + typewriter; 3: electric lawn-mower; 4: electric drill; 5: road drill). Relative risk of MI (ICD 410) was adjusted for covariates (smoking, body mass index, age, social class, education, marital status, shift work, housing area). * Significance, $p < 0.05$.*

distribution. The population attributable risk percentage (PAR) without correction for social class is PAR = 0.33. Correction for social class distribution in the source population leads to an attributable risk percentage of PAR = 0.27 suggesting that 27% of all MI in the source population may be attributable to subjective work noise. Consequently, subjective work noise appeared to be the second greatest risk factor for MI after smoking (PAR = 0.5).

From the literature it is known that the percentage of smokers increases with chronic noise[19]. We therefore studied the relationship between subjective work noise as a stressor and smoking and found a dose-dependent increase in the relative risk for smoking with subjective work noise. In noise category 3 smoking was identical to that in the reference group (categories 1 + 2). In category 4 smoking increased tendentially by 10% and in category 5 it increased significantly by 70%.

Discussion

A population attributable risk percentage of PAR = 0.27 for subjective work noise in relation to MI is unexpectedly high and might have been overestimated for various reasons. One possibility is that the subjective noise rating may have been influenced by the experience of MI, resulting in a systematic overestimation of noise by the MI patients. Such an overestimation of subjective noise could be due to the well-known fact that noise in combination with other stressful conditions is rated higher than without other stressors. It is probable that this subjective noise aggravation is more pronouced in the MI group than in controls. However, a small case-control study comparing noise level measurements with subjective noise rating has shown that only 8% of the controls and 16% of the MI patients overestimated the subjective noise load[19]. The magnitude of this kind of bias in our study is unknown, because no sound levels were measured in the MI group.

The 32% of non-responders in the controls entails the possibility of selection bias. The most probable effect seems to be a distortion in relation to social class. Subsequently we checked this and found that

Variable	RR	Significance
Body mass index (kg/m²)	1.05	0.001
Social class (worker/others)	0.71 *	0.015
Education (college degree/others)	0.60	0.002
Marital status (divorced + widowed/others)	1.86	0.000
Residential area (outskirts/inner city)	0.85	0.167
Shift work (yes/no)	0.72	0.053
Age (51 – 65/32 – 50 years)	1.64	0.095
Current smoking (yes/no)	3.10	0.000
Noise (categories (3 + 4 + 5)/(1 + 2))	2.47	0.009
Age by smoking	0.69	0.333
Noise by smoking	1.52	0.319
Age by noise	0.46	0.058
Noise by age by smoking	1.05	0.919

* Most of the other MI risk factors (smoking, high BMI, etc.) are more prevalent in workers.

Table 5. *Results of full model analysis including interaction terms.*

selection bias resulted in 29% workers in the control group whereas the source population contained 37% workers. Therefore selection bias may have influenced the results, but only to a limited extent.
The exclusion from both groups of the unemployed and persons in early retirement should not have influenced the results since this effect was similar in both groups.
The duration of work noise exposure has not been assessed since the original study focused on traffic noise. However, exposure misclassification due to missing information on length of exposure would dilute the true noise effect if this occurs at random, and bias is more likely to have a conservative impact since the migration rate will probably be higher due to noise at the workplace.
The lower noise-related relative MI risk at an older age indicates a noise-related self-selection. This may be caused by noise-sensitive people leaving a noisy place of work earlier than non-sensitive workers. Since case fatality in acute MI is about 50% only half of all MI cases are included in the study. This, however, would only influence the results if case fatality is noise-dependent, for which no hypothesis exists at the present time.
Hearing loss, in contrast to this, can be noise-dependent. But although the hearing threshold is shifted by noise-induced hearing loss the perceived loudness of noise well above the hearing level does not decrease (recruitment). Conductive hearing loss, on the other hand, which reduces perceived loudness independently of noise level, is not noise-induced. Therefore, systematic error due to the effect of hearing loss can be ruled out.
Moreover, the difference between subjective and objective noise rating seems to be of major importance. This difference is explained schematically in Figure 3. In general, sound parameters, which can be measured objectively, determine subjective noise perception to a degree of about 30% to 40%. Situative and personal influences together determine subjective noise perception to the same degree[7]. In our study we used a subjective loudness rating, which was determined by the work noise level to a degree of 70%, indicating that the sound level is more closely correlated to loudness than to noise disturbance parameters.
However, if our results do reflect a true noise effect, then there should also be a clear link between objective work noise parameters, i.e. noise levels, and cardiovascular risk. This has not been found in all previous studies, but this may be because nearly all studies on this relationship have shortcomings arising from two serious problems. The first is the suitability of the control group. Since the ideal "no noise" does not exist, objective noise studies must compare groups with clearly increasing noise levels and use the group with the lowest exposure as a reference. The second problem occurs at levels above 85 dB (A). In western industrialized countries, ear-protectors must be provided for levels greater than this. If the use of ear protectors by some study participants is not taken into account, noise effects will be underestimated. This is because people who suffer from noise stress are more likely to use ear protectors than those who are less sensitive to noise. If such people work below 85 dB (A) and therefore are not provided with ear protectors, their noise-induced stress will be higher than the noise stress of workers with 90–100 dB (A) external noise which is reduced by 20–30 dB due to ear protectors.
This seems to be the reason why one otherwise well designed case-control study[20] failed to show any cardiovascular risk of noise. Subjective noise rating in our study avoids these two problems, but it is open to bias due to overreporting and misclassification as discussed above. However, a prospective cohort study[21] of 1002 persons (about half males and females) over 11 years resulted in a noise related relative MI risk of 2.78

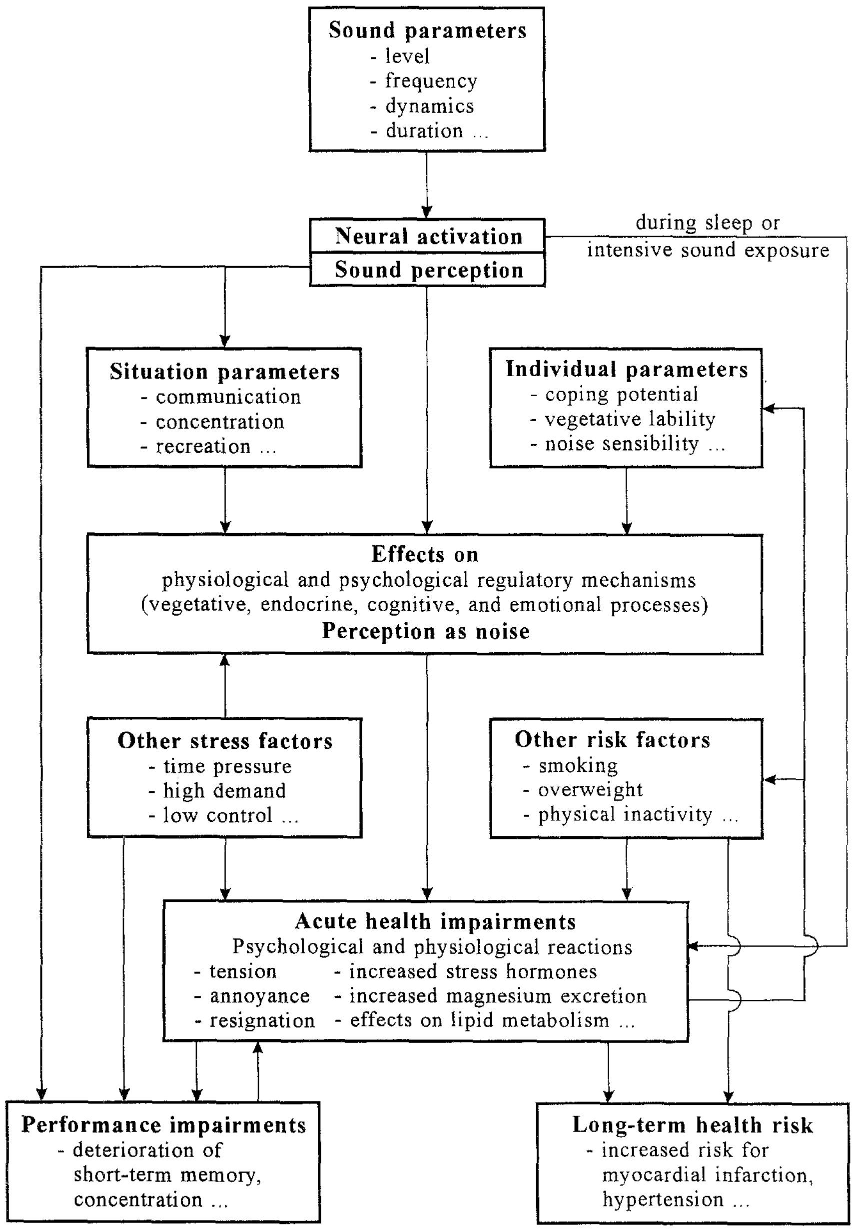

Figure 3. *Schematic relationship between psychophysiological effects of noise, work stress, risk factors and cardiovascular diseases.*

(95%-confidence interval: 1.01–7.63) and PAR = 0.15. This value is lower than in the presented study, but it can be explained by the low percentage of females under loud work noise exposure.

According to our present knowledge, subjective work noise has to be considered as a major risk factor in MI. Interdisciplinary studies on the relationship between cardiovascular diseases and work-related stressors including subjective and objective noise assessment are necessary to clarify the unresolved questions, especially the quantitative risk of MI due to work noise.

References

1 *Kristensen TS.* Cardiovascular disease and the work environment. A critical review of the epidemiologic literature on non-chemical factors. Scand J Work Environ Health 1989; *15*:165–179.

2 *Selye H.* The stress of life. New York: McGraw-Hill, 1956.

3 *Levi, L.* Emotional stress. Basel: Karger, 1967.

4 *Poppei M, Hecht K.* Stressorenwirkung und chronischer Stress in Abhängigkeit von Zuständen des Organismus und von Umweltkonstellationen. Wiss Z Humboldt-Universität 1980; *2*:667.

5 *Lazarus RS.* Psychological stress and the coping process: New York: McGraw-Hill, 1966.

6 *Wolf S.* A formulation of psychosomatic mechanism. Proc. Third World Congress of Psychiatry. Montreal: Univ Toronto Press, 1963.

7 *Guski R.* Psychische Auswirkungen von Umweltlärm. Aktuelle Fragen. Bundesgesundheitsblatt 38, 1995; *3*:89–94.

8 *Idzior-Walus, B.* Coronary risk factors in men occupationally exposed to vibration and noise. Eur Heart J 1987; *8*:1040.

9 *Ising H, Günther T, Havestadt C.* Blutdrucksteigerung durch Lärm am Arbeitsplatz. Bremerhaven: Wirtschaftsverlag, 1980.

10 *Ising H, Rebentisch E.* Comparison of acute reactions and long-term extra-aural effects of occcupational and environmental noise exposure. In: Vallet M, ed. Noise and Man '93. Vol 3, 280. Inrets, Arcueil Cedex, 1993.

11 *Babisch W, Ising H, Gallacher J, Sharp D, Baker I.* Traffic noise and cardiovascular risk. The Caerphilly and Speedwell studies, second phase. Risk estimation, prevalence, and incidence of ischemic heart disease. Archives Environ Health 1993; *48*:401.

12 *Babisch W, Elwood P, Ising H.* Road traffic noise and heart disease

risk: Results of the epidemiological studies in Caerphilly, Speedwell and Berlin. In: Vallet M, ed. Noise and Man '93. Vol 3, 260. Inrets, Arcueil Cedex, 1993.
13 *Melamed S.* Noise exposure, environmental annoyance and serum lipid/lipoprotein levels in blue-collar workers. The Cordis study. First International Symposium on Work Environment and Cardiovascular Disease. Copenhagen, 1995.
14 *Thompson S.* Epidemiology feasibility study: Effects of noise on the cardiovascular system. University of South Carolina, 1981.
15 *Thompson S.* Extraaural health effects of chronic noise exposure in humans [review]. In: Ising H, Kruppa B, eds. Noise and Disease. Stuttgart, New York: Gustav Fischer, 1993.
16 *Thompson S.* Summary of team 3: Non-auditory physiological effects. In: Vallet M, ed. Noise and Man '93. Vol 3, 288. Cedex: Inrets, Arcueil, 1993.
17 *Babisch W, Ising H, Kruppa B, Wiens D.* The incidence of myocardial infarction and its relation to road traffic noise. Environment International 1994; *20*:469.
18 *Babisch W, Ising H, Kruppa B, Wiens D.* Verkehrslärm und Herzinfarkt. Ergebnisse zweier Fall-Kontroll-Studien in Berlin. WaBoLu-Hefte 2/1992. Berlin. Institute for Water-, Soil- and Air Hygiene of the Federal Health Office, 1992.
19 *Mann HB.* Myokardinfarkt und Arbeitsbelastung. Dissertation, Göttingen, 1994.
20 *Thériault GP, Trembley CG, Armstrong BG.* Risk of ischemic heart disease among primary aluminium production workers. Am J Indust Med 1988; *13*:659–666.
21 *Bellach B, Dortschy R, Müller D, Ziese T.* Gesundheitliche Auswirkungen von Lärmbelastung – Methodische Betrachtungen zu den Ergebnissen dreier epidemiologischer Studien. Bundesgesundheitsblatt 1995; *3*:84–89.

Zusammenfassung

Subjektiver Arbeitslärm: Ein wesentlicher Risikofaktor für Herzinfarkt

In einer bevölkerungsbezogenen Fall-Kontroll-Studie wurde der Zusammenhang zwischen der subjektiven Arbeitslärmbelastung und dem Herzinfarktrisiko untersucht. 395 Herzinfarktpatienten im Alter von 31 bis 65 Jahren wurden mit 2148 Kontrollpersonen aus einer Zufallsstichprobe mit gleicher Alters- und Geschlechtsverteilung verglichen. Das relative Risiko für Herzinfarkt – adjustiert bezüglich mehrerer Einflussvariablen wie Rauchen, Alter, Sozialstatus usw. – stieg signifikant und monoton mit der Arbeitslärmbelastung an. Die subjektive Arbeitslärmbelastung erwies sich als der zweitwichtigste Risikofaktor für Herzinfarkt nach dem Rauchen. Mögliche Fehler wie z.B. Überbewertung der subjektiven Lärmbelastung werden diskutiert. Interdisziplinäre Studien zum Zusammenhang zwischen kardiovaskulären Erkrankungen und arbeitsplatzbezogenen Stressoren mit Erfassung der subjektiven und der objektiven Lärmbelastung sind notwendig, um das Herzinfarktrisiko durch Arbeitslärm zu quantifizieren.

Résumé

La perception subjective de bruit gênant au lieu de travail: Facteur de risque important d'infarctus du myocarde

Le rapport entre la perception subjective de bruit gênant et le risque d'infarctus du myocarde (IM) fait l'objet d'une étude comparative portant sur 395 malades (IM) âgés de 31 à 65 ans et 2148 cas témoins sortis d'un sondage aléatoire parmi la population générale tout en assurant la même distribution d'âge et de sexe. Il s'avère que – après la rectification exigée par les variables telles que consommation de tabac, âge, couche sociale, etc. – le risque relatif (RR) de IM augmente de manière significative et constante avec le gêne causé par le bruit au lieu de travail. Pour le IM, la perception subjective du bruit vécu au lieu de travail est le deuxième facteur de risque, son importance n'étant dépassée que par le tabagisme. Les auteurs discutent l'incidence possible d'une notification exagérée de bruit gênant. Afin de calculer le risque d' IM attributable au bruit perçu au lieu de travail, des études interdisciplinaires devraient être réalisées pour examiner les liens entre les maladies cardiovasculaires et les stresseurs liés au travail, y compris l'évaluation subjective et objective du bruit.

Address for correspondence

Prof. Dr. Hartmut Ising
Umweltbundesamt
Institut für Wasser-, Boden- und Lufthygiene
Corrensplatz 1
D-14195 Berlin