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Chronic Cortisol Increases in the First Half of the Night Caused by Road Traffic Noise

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56 children age 7 - 10 had a medical check-up and they and their mothers completed questionnaires. Additionally the children's excretion of free cortisol was measured by HPLC in two urine samples collected at 1 p.m. and in the morning. The children lived either at a busy road with 24 h lorry traffic or in quiet areas. At the side of the road the noise level was registered during five nights. In the bedrooms representative measurements of the short-term maximal sound level (L_{Amax} and L_{Cmax}) and of the frequency spectrum were taken. During the night on average every 2 minutes a lorry with L_{max} > 80 dB(A) passed by the houses. The indoor levels of the higher exposed half of the children were L_{max} = 33-52 dB(A) resp. 55-78dB(C)). The frequency spectrum had its maximum below 100 Hz. 74% of the higher exposed never opened their windows as compared to 25% in the lower exposed half group. The excretion of free cortisol and its metabolites in the first half of the night was significantly correlated to L_{Cmax} (co-variables: age, sex, and the day of the week) as well as to impaired sleep, memory and ability to concentrate. The cortisol excretion in the second half of the night was not correlated to the noise level. Disturbances of the normal circadian rhythm of cortisol can be quantified by the quotient of the cortisol excretion in the first half of the night in relation to that in the second half. Children under long-term road traffic noise exposure during the night had an increased risk of chronic stress hormone regulation disturbances. These disturbances were significantly correlated to L_{Cmax} and findings of allergy and/or asthma bronchial. Long-term low frequency noise exposure with Lmax < 55 dB(A) during the night resulted in chronic increases of children's excretion of free cortisol in the first half of the night and in serious disturbances of the circadian rhythm of cortisol. Indications of increased risks of asthma bronchial and allergies in noise exposed children with stress hormone regulation disturbances need further clarification

Keywords: Road traffic noise, low frequency noise, stress, children, circadian rhythm of cortisol

Introduction

In villages near the border to the former German Democratic Republic there was nearly no road traffic before 1990. Therefore no by-pass roads were built, but after the reunification of Germany the situation changed dramatically in some villages. One example is Barbis, Bad Lauterberg, near the Harz Mountains. Heavy goods traffic from the Hannover region to the Halle-Bitterfeld industrial area is flowing day and night through the narrow street. On average every 2 minutes during the night, a heavy lorry passes by the houses within a distance of 1-3 m. Complaints from the population was furthered to the Federal Environmental Agency and a pilot study was planned to investigate health effects.

It is generally accepted that noise has the potential to cause stress reactions [for a review see Ising et Braun, 2000). Spreng (2000) described the activation of the hypothalamic-

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Table 1. Testpersons and indoor noise levels

	n	$L_{max,m}$ [dB (C)]	$L_{max,m}$ [dB(A)]	Age [years]	Height [cm]	Weight [kg]
Total group	56	30 – 78	20– 53	7 – 13	119 – 175	19 –72
50% high noise	28	55 – 78	26–53	9,8 ± 2,0	143 ± 14	38 ± 12
50% low noise	28	30 – 54	20– 43	9,7 ± 2,0	145 ± 13	42 ± 13

pituitary-adrenal system via the amygdala, a subcortical region of the CNS. The amygdala is able to identify noise stimuli, which signal a danger i.e. the noise of an approaching lorry. This mechanism helps us to survive dangerous situations by triggering quick reactions and the release of ACTH and cortisol. Since our hearing system and the subcortical regions of the CNS are active also during sleep, traffic noise may trigger cortisol release also in sleeping persons. According to Born and Fehm (2000) a reduction of the plasma cortisol concentration to a minimum in the first half of the night is essential for recreation during sleep and for different memory processes. Noise induced cortisol increases during the first half of the night will therefore have more detrimental effects on health if repeated chronically than noise stress during the last part of the night when the cortisol concentration is approaching its normal maximum, which is reached in the morning after awakening.

Experimental night-time noise exposure does not lead only to increases of the total cortisol excretion during the night but in several individuals also to significant decreases. Since the plasma cortisol concentration is absolute 10 times higher in the morning than at midnight these decreases are caused by a reduction of the cortisol maximum in the morning. Therefore, the highest probability to find significant noise induced increases of cortisol will be in the first half of the night. Furthermore, the quotient of the cortisol excretion during the first half of the night divided by the excretion in the second half should be a useful parameter to quantify noise induced disturbances of the cortisol regulation.

Method

The inhabitants of Barbis were invited to a meeting on the subject noise induced health effects and a discussion of the planned study. About 40 families living more or less near the street B 243 and - after an additional invitation - 10 families from a quiet village agreed to co-operate. It was agreed that children in the age range between 7 – 13 years should have a general medical check up, including questionnaires, which should be completed by the children and their mothers. The questionnaires were identical to those used in the Munich airport studies (Evans et al.1995, 1998). Among other things the children's subjective

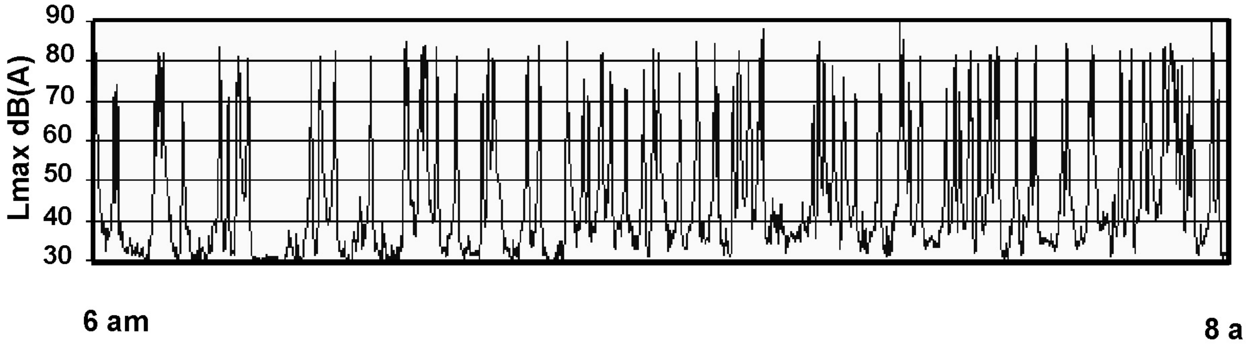

Figure 1. Time dependence of the outdoor noise level measured 3m beside the road measured as L_{Fmax} every 4 s between 6 and 8h am.

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Table 2. Mean sound levels (L_{eq}), 1% maximal levels (L_1) and numbers of passing lorries with $L_{max} \geq 80$ dB(A) during five nights.

Night	$L_{eq,8h}$ dB(A)	L_1 dB(A)	n, $L_{max} \geq 80$ dB(A)
Tu/We	67.2	83	218
We/Th	66.8	83	203
Th/Fr	66.6	85	247
Fr/Sa	65.1	83	118
Su/Mo	69.7	86	315
mean ± sd	67.1 ± 1.7	84.0 ± 1.4	220 ± 72

Table 3. Mean sound levels (L_{eq}), 1% maximal levels (L_1) and numbers of passing lorries with $L_{max} \geq 80$ dB(A) per hour in a typical night.

Time	L_{eq} dB(A)	L_1dB(A)	n (L_{max}≥80dB(A)
22-23	65,7	83	20
23-24	64,1	82	15
00-01	65,1	82	17
01-02	64,4	81	17
02-03	66,2	84	23
03-04	67,3	84	27
04-05	70,4	85	43
05-06	69,7	85	56
8h	67,2	83	218

experience of noise, stress and sleep as well as their ability to concentrate and to memorize was assessed. From the children two urine samples were collected during one night, after gentle awakening by the mothers at 1 h in the night and in the morning. The collection periods were documented by the mother and in the following morning, the urine was weighed, the pH adjusted to 2-3 and 3 samples of 10 ml each were deep frozen. Free cortisol, 20α-dehydrocortisol and cortisone were analysed by HPLC (Schöneshöfer et al.1985, 1986).

During the field phase the sound level was recorded as 4s mean levels (L_{eq}) und maximal level (L_{Fmax} , time constant "fast") for five days and nights (Norsonic 110 & 116 in combination with a weather proof condensor microfon). In the noise exposed sleeping rooms of the participating children representative short term measurements of the indoor L_{Fmax} of passing lorries were carried out with the frequency weightings "A" and "C". The lower indoor noise levels were assessed by an acoustic expert on the basis of outdoor traffic noise, type of window, and position of window during the night (open or closed). The statistical data analysis included multiple regression analyses with age, sex, social class etc. as co-variates.

56 children were included in the study group. Part of the analysis used a comparison of the upper and the lower half group concerning indoor noise levels in dB(C). The mean maximal road traffic noise levels indoor in dB(A) and dB(C) are given in Table 1 for the total group and the two half groups together with number, age, height and weight of the test persons. There were no statistically significant differences between the half groups concerning age, height or weight.

Results

The maximal free field sound level of lorries passing by reached 90 dB(A) at a distance of 3 m from the roadside kerb and at a distance of 8 m from the nearest house. Figure 1 shows the time

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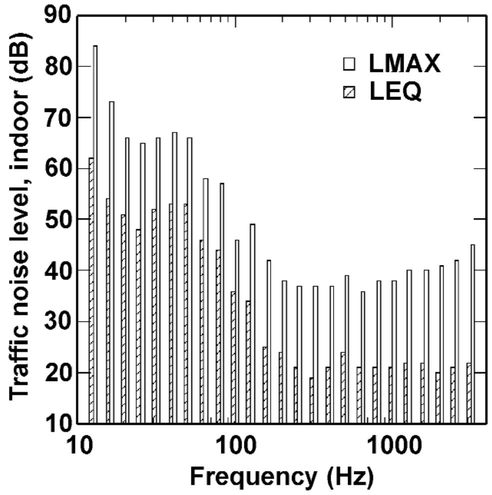

Figure 2. Third octave spectrum of indoor noise. White: L_{max}, L_{Cmax} = 78 dB, L_{Amax} = 53 dB Hatched: L_{eq}, L_{Ceq} = 59 dB, L_{Aeq} = 34 dB

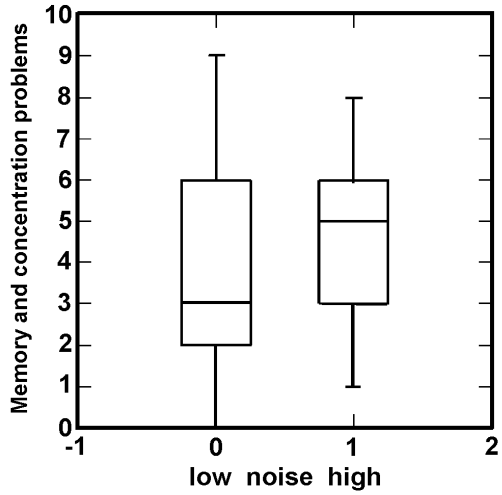

Figure 3. Box plot (median, 25%-, 75%-, 5%- and 95%-values) of memory and concentration problems in lower (0) and higher (1) noise exposed half group

course of the sound level measured with time constant „fast“ in a typical morning between 6 and 8am. The results of the sound level recording during the five days of the field experiment are given in Table 2. The mean level per night (10 pm till 6 am) varied between 65 and 70 dB(A) and resulted to an average of 67.1 ± 1.7 dB(A). The number of passing lorries with L_{Fmax} > 80 dB(A) was found to be 220 ± 72. In Table 3 these results are presented for every hour and show a typical night. Before midnight the traffic noise reached its minimum. In this time every 4 minutes a loud lorry passed by the houses.

The mean level at daytime (6am to 10pm) was only 2-3 dB higher than the night time mean level. In the centre of the village the level was higher, because the house fronts were at a distance of 1–3 m from the road and reflected the noise. Level calculations on the basis of the German law (16B/mSchV, 1990) with a traffic flow of 18000 cars per 24 hours with 35% lorries and a speed of 50 km/h led to a night time L_{eq} = 75dB(A).

Most of the highly exposed houses were equipped with special sound insulating windows. Never the less the low frequency noise of passing lorries could be clearly heard. A third octave spectrum of the mean L_{Fmax} and the L_{eq} in one of the highest exposed rooms is shown in Figure 2. The mean L_{Fmax} amounted to 78 dB(C) resp. 53 dB(A). As shown in Table 1 the mean indoor L_{Fmax} varied between 55 and 78 dB(C) respective 26 and 53 dB(A) in the higher exposed half group. Since the group was divided according to L_{Cmax} there is some overlapping of L_{Amax} in the subgroups.

Nine of the 56 partcipating children had chronic allergies and/or asthma bronchial.
In the higher exposed half group 74% of the children never opened their windows as compared to 25% in the lower exposed half group.

The questionnaire results on memory and concentration problems respective sleeping problems (sum of "restless sleep" and of problems with falling asleep in the evening and after awakening during the night) for both subgroups are shown in Figures 3 and 4. The higher noise exposed children had significantly more problems with concentration/memory and sleeping. Even after excluding the children with indoor L_{max} > 45 dB(A) there existed a significant correlation between L_{Cmax} and awakening during sleep as well as problems to fall asleep again (co-variables: age sex social status).

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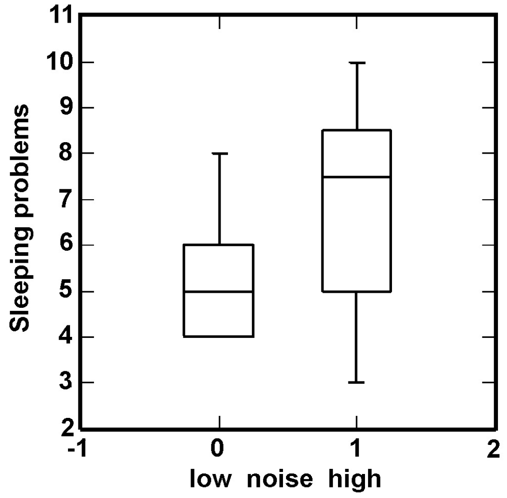

Figure 4. Box plot of sleeping problems in lower (0) and higher (1) noise exposed half group

The mean excretions of free cortisol and its metabolites in the first and second half of the night are shown in Table 4. In the second half of the night the excretions are about five times as high as in the first half. The quotients of the excretions in the first half divided by the excretions in the second half of the night of free cortisol and its metabolites are listed in Table 5.

The medians of all the quotients lay between 0.15 and 0.17.

Since all these parameters were not normally distributed they were transformed to logarithms and multiple correlation analyses were carried out with age, sex and the day of the week, when urine was collected, as co-variables. The excretions of free cortisol and its metabolites were significantly correlated to L_{Cmax} only in the first half of the night (see Table 6).

Memory and concentration problems were significantly higher in the quarter of the group with the highest excretion of free cortisol in the first half of the night (Figure5). They were not correlated to metabolites of cortisol in either half of the night nor to cortisol in the second half of the night (Table 7).

Multiple correlation analysis revealed a significant correlation of sleeping problems to cortisol in the first half of the night – but not in the second half – and to the indoor maximal level in dB (C) (L_{Cmax}) (Table 7).

Multiple correlation analysis with the logarithm of the quotient of free cortisol plus its two metabolites log(q-sum) = log[(cort1+20α-dhc1+cortison1)/(cort2+20α-dhc2+cortison2)] revealed a significant correlation to sex (girls'

Table 4. Cortisol, 20 -dehydrocortisol and cortison excretion in the first and the second half of the night

	Cortisol	20α-Dehydrocortisol	Cortison
First half of the night (n=48)			
Mean [ng/h]	113	175	247
sd	178	152	288
second half of the night (n=53)			
Mean [ng/h]	961	605	1207
sd	585	458	779

Table 5. Quotient of the excretions in the first and the second half of the night of free cortisol and its metabolites (Q-Sum:[Q-Cortisol+ Q-20 -Dhc+ Q-Cortison]/3).

	Q-Cortisol	Q-20α-Dhc	Q-Cortison	Q-Sum
Median	0.152	0.172	0.169	0.162
Minimum	0.018	0.006	0.010	0.011
Maximum	1.139	1.095	1.101	1.109
Mean	0.242	0.209	0.237	0.221
Standard Dev	0.248	0.189	0.234	0.205

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Table 6. Multiple correlation of L_{Cmax} to cortisol and its metabolites

First half of night

Log(cortisol-1) N: 46 Multiple R: 0.480 Squared multiple R: 0.230

Effect	Coefficient	t	P(2 Tail)
Age	0.076	1.439	0.158
SEX	-0.320	-1.464	0.151
Weekday	0.207	2.468	0.018
LCmax	0.025	2.542	0.015

Log(20α-dhc-1) N: 46 Multiple R: 0.475 Squared multiple R: 0.226

Effect	Coefficient	t	P(2 Tail)
Age	0.080	1.582	0.121
SEX	-0.251	-1.204	0.236
Weekday	0.126	1.568	0.125
LCmax	0.026	2.771	0.008

Log(cortison-1) N: 46 Multiple R: 0.498 Squared multiple R: 0.248

Effect	Coefficient	t	P(2 Tail)
Age	0.122	2.276	0.028
SEX	-0.319	-1.439	0.158
Weekday	0.144	1.694	0.098
LCmax	0.023	2.276	0.028

Log(cort-1+20α-dhc-1 +cortison-1) N: 46 Multiple R: 0.518 Squared multiple R: 0.268

Effect	Coefficient	t	P(2 Tail)
Age	0.101	2.137	0.039
SEX	-0.280	-1.439	0.158
Weekday	0.145	1.942	0.059
LCmax	0.024	2.720	0.010

Second half of night

Log(cortisol-2) N: 51 Multiple R: 0.408 Squared multiple R: 0.166

Effect	Coefficient	t	P(2 Tail)
Age	0.123	2.337	0.024
SEX	0.358	1.718	0.093
Weekday	0.068	0.831	0.410
LCmax	-0.006	-0.601	0.551

Quotient of excretions in first/second half of night

Log(q-sum) N: 46 Multiple R: 0.424 Squared multiple R: 0.180

Effect	Coefficient	t	P(2 Tail)
Age	0.006	0.107	0.916
SEX	-0.558	-2.321	0.025
Weekday	0.066	0.712	0.481
LCmax	0.024	2.165	0.036

quotient higher than boys'), L_{Cmax} and allergy/asthma (Table 7).

Figure 6 shows the scatter plot of this log(q-sum) as a function of L_{Cmax} with the regression line from the multiple regression analysis including sex and allergy/asthma.

The systolic blood pressure was significantly correlated to body weight, arm circumference (negative), pulse frequency and social status but not to L_{Cmax} or any of the cortisol or metabolite parameters.

Discussion

It is well known that effects of low frequency noise exposure are underestimated by weighting the sound level with the 'A' curve. For this reason the German standard DIN 45680 (1997) "Measurement and evaluation of low frequency noise immissions in the neighbourhood" was developed. This present study confirms this view. Additionally it indicates that a limitation to $L_{max} \leq 45$ dB(A) as suggested by WHO (2000) does not protect against awakening due to low frequency traffic noise (lorry noise). It is necessary, therefore, to develop safer limits for low frequency night-time noise.

The main purpose of this study was to test the hypothesis that noise generally causes more cortisol increases in the first half of the night, because some of the exposed persons reacted with cortisol decreases the second half of the night. In agreement with this hypothesis we found the indoor L_{max} significantly correlated to

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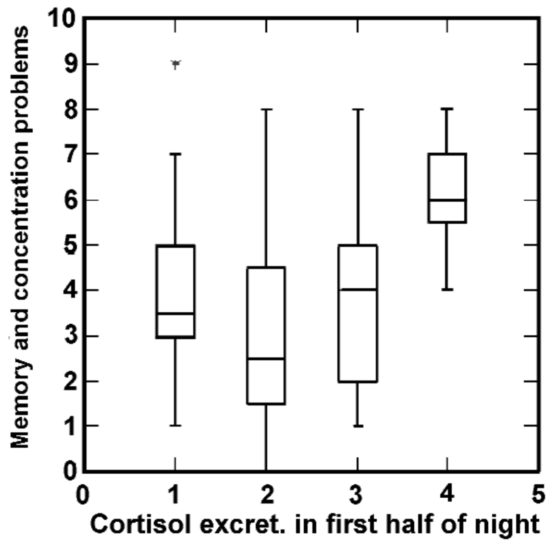

Figure 5. Box plot of memory and concentration problems in dependence of the free cortisol excretion in the first half of the night

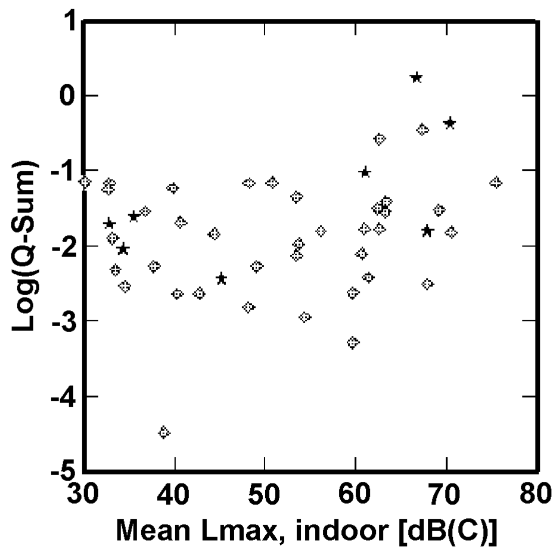

Figure 6. Scatter plot of the logarithm of the quotient of free cortisol plus its two metabolites (log(q-sum)) as a function of L_{Cmax} (log(q-sum) = log[(cort1+20α- dhc1+cortison1)/(cort2+20α-dhc2+cortison2)]) Stars: allergies and/ asthma

cortisol and its metabolites in the first half of the night but not in the second half (co-variables age, sex and week-day).

In the multiple correlation analysis the day of the week when the urine was sampled was included in the co-variables because Maschke et al (2001) described a weekly rhythm of cortisol. This influence was reduced considerably when the excretion of cortisol and/ or its metabolites in the first half of the night was related to the excretion in the second half.

Although this quotient of cortisol and its metabolites turned out to be most useful, the absolute excretions per hour were used in multiple correlation analysis of sleeping and memory/concentration problems in order to show the predominant importance of free cortisol in the first half of the night.

We found correlations of sleeping and memory/concentration problems with the cortisol excretion in the first half of the night but not in the second half nor with cortisol metabolites in either half of the night. This is in accordance with the results of Born and Fehm (2000), who argue that a condition for healthy sleep is the normal physiological decrease of stress hormones in the first half of the night to an absolute minimum. This minimum is also said to be essential for memory formation.

Multiple correlations were calculated with the quotients of the each cortisol/metabolite parameter and with the quotient of the sum of free cortisol and its two metabolites. Since the latter seems to be affected to a lower degree by random variations (i. e. due to the biochemical analysis) it was used to calculate the correlation to L_{cmax} and the findings of allergy and/or asthma (co-variables: age, sex, social status; the week-day had a negligible effect). Both L_{Cmax} and allergy/asthma were significantly correlated to the quotient of the sum of cortisol and its metabolites. This may indicate that long term disturbances of the normal circadian rhythm of cortisol increases the risk of allergies and asthma or that these diseases increase the risk of cortisol regulation disturbances. Additionally it may be that an other factor being correlated to noise and asthma/allergies – for example indoor dust due to closed windows – plays an important role. Further research is necessary for clarification. However, the correlation between noise exposure and cortisol regulation disturbances seems to be a causal one. This view is affirmed

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Table 7. Multiple correlations

Memory and concentration problems

N: 40 Multiple R: 0.554 Squared multiple R: 0.306

Effect	Coefficient	t	P(2 Tail)
Age	0.119	0.610	0.546
Sex	-0.517	-0.658	0.515
Social st.	-0.207	-0.815	0.421
LCmax	0.037	0.988	0.331
Weekday	-0.380	-1.280	0.210
Log(Cort.1)	1.619	2.116	0.043
Log(Dhcort.1)	-0.553	-0.601	0.552
Log(Cort.2)	-0.361	-0.650	0.521

Sleeping problems

N: 39 Multiple R: 0.712 Squared multiple R: 0.507

Effect	Coefficient	t	P(2 Tail)
Age	-0.169	-1.337	0.191
Sex	-0.405	-0.777	0.443
Social st.	-0.472	-2.768	0.009
LCmax	0.053	2.200	0.035
Weekday	-0.332	-1.739	0.092
Log(Cort.1)	0.764	1.735	0.093
Log(Cort.2)	-0.272	-0.827	0.414

Log(Quotient of cortisol + metabolites)

N: 41 Multiple R: 0.529 Squared multiple R: 0.280

Effect	Coefficient	t	P(2 Tail)
Age	0.053	0.886	0.382
SEX	-0.602	-2.535	0.016
Social st.	-0.064	-0.808	0.424
LCmax	0.019	2.096	0.043
Allergy/asthma	0.803	2.415	0.021

Systolic blood pressure

N: 48 Multiple R: 0.608 Squared multiple R: 0.370

Effect	Coefficient	t	P(2 Tail)
Weight	1.007	3.417	0.001
Arm	-2.554	-2.313	0.026
Puls	0.276	2.131	0.039
Social status	2.616	2.289	0.027
LCmax	0.020	0.157	0.876

by the findings of Melamed et al (1996). Test persons with high work noise exposure, who did normally not use ear protectors, were found to have a disturbed circadian cortisol rhythm. After working for one week with ear protectors, which reduced the noise exposure up to 30 dB, the circadian rhythm had normalised. Since a chronically disturbed cortisol rhythm will also reduce the recovery function of sleep (Born and Fehm, 2000), long term health risks are to be expected as a consequence of nocturnal traffic noise exposure.

Evans et al (1998) reported a noise-related increase of the blood pressure in children living near the new Munich airport. In contrast to that we did not find a relationship of traffic noise and blood pressure. It may be that the different type of the noise – flight noise in contrast to road traffic noise – plays a role. A second difference in the Munich study was a non significant effect of noise on the cortisol excretion. This can be explained by the fact that Evans did not measured free cortisol but total cortisol. In the Innsbruck study (Evans et al. 2001) significant chronic increases of nocturnal excretions of free cortisol and 20-α dehydrocortisol were found in children with moderate road traffic noise exposure as compared to controls from a quiet neighbourhood. It is an interesting question why in the Innsbruck study the excretion of free cortisol during the whole night was increased in contrast to the Barbis study where only the excretion in the first half of the night was increased. A possible explanation might be higher indoor sound levels in Innsbruck, because in Barbis the exposed children slept behind closed windows with high sound insulation. This

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would be in agreement with the different results of both studies concerning the blood pressure.

Conclusions

Children under long-term road traffic noise exposure during the night had an increased risk of chronic stress hormone regulation disturbances. Although most of the noise exposed bedrooms had sound insulating windows so that the maximal sound level indoor was below 55dB(A), the cortisol excretion in the first half of the night was significantly increased. This increase was correlated to impaired sleep, memory and ability to concentrate. Additionally the results may indicate increased risks of diseases such as asthma bronchial and allergies. A case control study was started to investigate a possible correlation of chronic low frequency traffic noise exposure and these diseases.

Acknowledgement

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References

Born, J., Fehm,H.L. (2000) The Neuroendocrine Recovery Function of Sleep. *Noise & Health*, 7, 25-37

Born,J., Plihal,W. (2000), Gedächtnisbildung im Schlaf: Die Bedeutung von Schlafstadien und Streßhormonfreisetzung, *Psychologische Rundschau* (im Druck).

DIN 45680 (1997) Messung und Bewertung tieffrequenter Geräuschimmissionen in der Nachbarschaft, Beuth Vlg. Berlin.

Evans, G.W., Hygge, S., and Bullinger, M. (1995). Chronic noise and psychological stress. *Psych. Sci*. 6, 333-338

Evans, G.W., Bullinger, M. and Hygge, S. (1998) Chronic noise exposure and physiological response: a prospective study of children living under environmental stress. *Psychological Science* 9: 75-77.

Evans,G.W.,Lercher,P., Meis,M., Ising,H., Kofler, W. (2001). Typical Community Noise Exposure and Stress in Children. *J.Acoust.Soc.Am*.109(3):1023-7.

Ising,H. and Braun,C. (2000), "Acute and chronic endocrine effects of noise: Review of the research conducted at the Institute for Water, Soil and Air Hygiene". *Noise & Health*, 7, 7-24

Maschke, C. Harder,J. Ising, H. Hecht, K. and Thierfelder,W. (2001) Stress hormone changes in persons under simulated night noise exposure. *Noise & Health* (in print).

Melamed, S., Bruhis, S. (1996) The effects of chronic industrial noise exposure on urinary cortisol, fatigue, and irritability. *JOEM* 38: 252-256.

Schoeneshoefer, M., Kage, A., Weber, B., Lenz, I., and Kottgen, E. (1985). Determination of urinary free cortisol by on-line liquid chromatography. *Clin. Chem.* 31, 564-568.

Schoeneshoefer, M., Weber, B., Oelkers, W., Nahoul, K., and Mantero, F. (1986). Measurement of urinary free 20α-dihydrocortisol in biochemical diagnosis of chronic hypercorticoidism. *Clin. Chem*. 32, 808-810.

Spreng, M. (2000) Central nervous system activation by noise. *Noise & Health* 7: 49-57.

WHO (2000) Guidelines for community noise. World Health Organization, Geneva.