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Effects of Nocturnal Aircraft Noise
Volume 3
Stress Hormones

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125 pages
53 figures
49 tables
38 references

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aircraft noise, stress, stress hormones, cortisol, adrenaline, noradrenaline, electrolytes, sodium, potassium, magnesium, calcium, mixed model

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Effects of Nocturnal Aircraft Noise (Volume 3): Stress Hormones

DLR-Forschungsbericht 2004-09/E, 2006, 125 pages, 53 figures, 49 tables, 38 references

A sleep laboratory study with 128 subjects was run using all night urine samples to investigate stress effects by nocturnal aircraft noise on the excretion of stress hormones (catecholamines, free cortisol) and electrolytes. 112 subjects served as experimental groups, and they were exposed to aircraft noise of various intensities (maximum sound pressure levels between 45 and 80 dB(A)) and frequencies (between 4 and 128 noise events per night) during nine consecutive nights between 11 pm until 7 am. A validation of the laboratory results took place by means of a field study which was conducted with 64 residents living close to Konrad-Adenauer-Airport Cologne/Bonn. For the laboratory study, there is no significant influence of aircraft noise, i.e., significant effects of the aircraft noise parameters maximum noise level LAS,max, number of aircraft noise events (level frequency), energy equivalent noise level LAS,eq on any of the excretions of stress hormones or electrolytes. There are no dose-response relations detectable. Age of the subjects or the degree of pre-annoyance by aircraft noise is of no statistical importance on stress hormone excretions. For the field study none of the parameters investigated shows any significant difference due to night aircraft noise. However, excretion rates of electrolytes and cortisol are significantly lower than in the laboratory study. It is discussed that the electrolyte excretion is strongly depending on nutrition, and choice of methods is viewed critically with respect to the assessment of stress hormones and nocturnal aircraft noise.

Fluglärm, Schlaf, Stress, Stresshormone, Cortisol, Noradrenalin, Adrenalin, Elektrolyte, Natrium, Kalium, Magnesium, Calcium, mixed model

(in englischer Sprache veröffentlicht)

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Nachtfluglärmwirkungen (Band 3): Stresshormone

DLR-Forschungsbericht 2004-09/E, 2006, 125 Seiten, 53 Bilder, 49 Tabellen, 38 Literaturstellen

In einer Schlaflaborstudie wurden an 128 Versuchspersonen die Wirkungen von Nachtfluglärm als Stressor auf die Exkretion von Stresshormonen (Katecholamine, freies Cortisol) und Elektrolyten im Nachtsammelurin untersucht. 112 Personen stellten die Experimentalgruppe dar, die Fluglärm unterschiedlicher Lautstärke (Maximalpegel zwischen 45 und 80 dB(A)) und Anzahl (zwischen 4 und 128 Ereignisse pro Nacht) während neun aufeinander folgender Nächte von 23:00 Uhr bis 07:00 ausgesetzt wurde. Zur Überprüfung der Laborergebnisse wurde eine Feldstudie mit 64 Versuchspersonen durchgeführt, die in der Nähe des Konrad-Adenauer-Flughafens Köln/Bonn wohnten. In der Laborstudie ergeben sich keine signifikanten Einflüsse auf Stresshormon- und Elektrolytausschüttung durch Fluglärm, d.h. keine signifikanten Einwirkungen durch Maximalpegel LAS,max , Anzahl der Fluggeräusche (Pegelhäufigkeit) oder äquivalenten Dauerschallpegel (LAS,eq). Dosis-Wirkungsbeziehungen sind nicht nachweisbar. Weder das Alter noch die Vorbelästigung durch Fluglärm ist von signifikanter Bedeutung für die Stresshormon-Ausschüttung. Keiner der untersuchten Parameter zeigt im Feldversuch signifikante Veränderungen unter Nachtfluglärm. Jedoch sind die Exkretionsraten von Elektrolyten und Cortisol im Feldversuch signifikant niedriger als im Labor. Es wird diskutiert, dass die Elektrolyt-Ausscheidung stark von der Nahrungsaufnahme abhängt, und die Methodik wird hinsichtlich der Stresshormone kritisch beurteilt.

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List of Abbreviations

Abbreviation	Meaning
AAS	atomic absorption spectrometry
AMSAN	isolation facility (Arbeitsmedizinische Simulationsanlage)
ANE	aircraft noise events
dB	decibel, physical unit of the sound pressure level
dB(A)	physical unit of the A-weighted sound pressure
DIN	Deutsches Institut für Normung e.V.
EIA	enzyme immunoassay
g	gram(s)
h	hour
HCl	hydrogen chloride
HPLC	high performance liquid chromatography
ISE	ion sensitive electrode
kHz	kilohertz, physical unit of frequency
L_{AS}	A-weighted sound pressure level measured with time-weighting "slow"
L_{eq}	A-weighted equivalent continuous sound level measured with time-weighting "slow"
$L_{AS,max}$	A-weighted maximum sound pressure level measured with time-weighting "slow"
LRA	logistic regression analysis
µL	microliter
m	meter(s)
min	minute(s)
mL	milliliter
n	nano
RIA	radioimmunoassay
SE	standard error
sec	second(s)
SPL	sound pressure level
STRAIN	Study on Human Specific Response to Aircraft Noise

1 Introduction

According to the generally accepted stress model stressors trigger a chain reaction, i.e. perception is followed by cerebral evaluation resulting finally into secretion of appropriate hormones that influence the reaction to the original stress [Selye 1946, 1957]. The original stress model was extended during the past by many authors who emphasized different aspects, as e.g. it is "appraisal" that leads to stress. It is not mere perception of what event occurs but also how this event is perceived and interpreted [Lazarus 1966]. Henry and Stephens [1977] put weight to social aspects as well.

Noise, defined as "unwanted sound events", and thus being considered as a physical stress factor, may be perceived aurally, registered, and processed in the brain activating eventually the autonomous nervous system and the endocrine system and causing in the end, the secretion of catecholamines and cortisol. Finally, these act on the sub-cellular level influencing electrolyte fluxes by changes of ion channels.

However, the amount of hormone productions due to noise stress is contradictory and disputed [Jansen 2000, Babisch 2003]. Pioneers in this field, Osada et al. [1969] and Carter et al. [1994] found no increase of catecholamine productions due to noise in general (street, factory) of up to L_{eq} = 60 dB(A) respectively, with 50 trucks or planes at maximum sound pressures of up to 72 dB(A) (9 subjects, 4 laboratory nights, 2 of them with noise exposure). In the laboratory with 64 nocturnal flight noise events at maximum SPLs of 65 dB(A), Maschke [1992] observed an increase of adrenaline excretion, as well as an increase of cortisol excretion in correspondence with the frequency of flight events with maximum SPLs of 75 dB(A). 8 subjects were studied during 10 nights. There was no control group in this experiment. In a field study, Maschke et al. [1995] detected a transient catecholamine increase in 7 airport residents, who were additionally exposed to aircraft noise events (frequency 16 or 64) with maximum SPLs of 55 to 65 dB(A) during 4 noise-exposed nights. They also exhibited a

temporarily shifted increase in the cortisol excretion. In a field study conducted by Harder et al. [1999], a total of 16 airport residents were also exposed to 32 additional flight noise events with an $L_{AS,max}$ of 65 dB(A) during 40 nights. In this case, a substantial change of the average cortisol excretion could not be observed. Based on the regrouping of the study subjects and on the questionable extrapolation of nocturnal cortisol secretion to 24 h values, that result is interpreted as a significant increase for certain groups of people. Kastka et al. [1999] did not detect any cortisol increase in his study (112 subjects, urine samples during the day). Braun [2001] investigated 18 subjects serving as control for 3 nights each, and 26 subjects for 4 nights each with traffic (street) noise in a field study. No changes of adrenaline or noradrenaline excretions were found. Cortisol excretion was enhanced with noise exposure only, when findings were re-calculated.

Summarized, the results published on stress hormone excretion after traffic or aircraft noise exposure are very confusing. Therefore, this study presented is to repeat several aspects of former studies with a much larger pool of subjects and exposure nights to shed some light on those contradictory results.

The hypothesis of the present study here is: nocturnal aircraft noise causes increased stress hormone and electrolyte excretions, respectively the null hypothesis reads: no relevant difference between excretion rates.

2 Study design and methods

2.1 Study design

Data sampling for the study commenced in September 1999 and ended in June 2003. Table 2.1 shows names, time periods and types of the different study parts.

Name	Study period	Type of study
STRAIN I	September until November 1999	Laboratory
STRAIN II	May until July 2000	Laboratory
STRAIN III	February until April 2001	Laboratory
STRAIN V	September 2001 until May 2002	Field
STRAIN VI	May 2002 until November 2002	Field
STRAIN IV	March until June 2003	Laboratory

Table 2.1: Study periods of the different parts of the study STRAIN (STudies on human specific Response to Aircraft Noise).

In the laboratory studies, 128 subjects were investigated for 13 consecutive nights, whereas in the field studies 64 volunteers were observed for nine consecutive nights. For comparative reasons, both the laboratory and the field studies commenced on a Monday evening.

In the laboratory studies, the simulation facility of the DLR-Institute of Aerospace Medicine allowed for the simultaneous investigation of eight subjects. The first of the 13 observation nights served as adaptation, the second as baseline and nights 12 and 13 as recovery. All of these nights were noise-free. A control group of 16 subjects was used to investigate the influence of the laboratory situation on otherwise undisturbed sleep and therefore the subjects did not receive any noise at all. The experimental group consisting of the remaining 112 subjects received between 4 and 128 air-

craft noise events (ANEs) per night with differing maximum sound pressure levels (SPL) during nine consecutive nights (nights 3 to 11). Lights were turned off at 11 pm and on again at 7 am, which allowed for a maximum sleep period time of 8 hours. In total, 1072 nights containing aircraft noise and 592 nights without aircraft noise (adaptation, baseline, recovery, and control) were investigated.

In the field studies, the homes of residents living in the vicinity of Cologne/Bonn Airport were selected in a way that the exposure to aircraft noise was high on one hand, but the exposure to other kinds of traffic noise, especially road traffic noise, was as low as possible on the other hand. Because flight paths change due to alternating weather conditions and the frequency of planes taking off and landing depends on the weekday, the study period consisted of nine consecutive nights, including weekends. Beside noise levels outside and inside the bedrooms, exactly the same data as in the laboratory studies (see below) were collected in the field. In contrast to the laboratory studies, subjects participating in the field studies were allowed to individually choose sleep period times with the requirement that sleep period times included the time period between midnight and 6 am. In total, 64 subjects were investigated in 576 nights during the field studies.

In total, 2,240 subject nights were investigated in both laboratory and field studies together. 20 volunteers participated in both, laboratory and field studies.

The study protocol was approved by the ethics commission of the Medical Association of the district North Rhine, Germany. Subjects were instructed according to the Helsinki declaration, participated voluntarily and were free to discontinue their participation at any time without explanation.

Study subjects received an allowance amounting to € 75 (field) and € 55 (laboratory) per observation night. Training of computer-assisted performance tests prior to the start of the study was reimbursed with up to € 350,-.

2.2 Acoustics

2.2.1 Acoustics in the laboratory studies

During nights 3 to 11 between 4 and 128 noise events of starting or landing planes with maximum sound pressure levels (SPL) from 50 to 80 dB(A) were played back between 11 pm and 7 am. In the last laboratory study STRAIN IV aircraft noise events (ANEs) with maximum SPLs of 45 dB(A) were additionally played back. With a constant difference of 5 dB(A) between events, 14 different aircraft noise events were applied in total.

		Number of Noise Events starting						**Number of Noise Events landing**					
		4	**8**	**16**	**32**	**64**	**128**	**4**	**8**	**16**	**32**	**64**	**128**
Maximum SPL $L_{AS,max}$ in dB	**45**											**32**	
	50			16	16	16	16			16	16	16	16
	55	**24**	16	16	16	16	16	16	16	16	16	16	16
	60	**24**	16	16	16	16		16	16	16	16	16	
	65	16	16	16	16	16		16	16	16	16	**40**	
	70	16	16	16	16			16	16	16	16		
	75	16	16	16				16	16	16			
	80	16	16					16	**8**				

Table 2.2: Combinations of maximum SPL at the sleeper's ear and number of aircraft noise events per night in the laboratory studies STRAIN I to IV (e.g. 24 subject nights with 4x60 dB(A) at the sleeper's ear). Frequencies other than 16 are highlighted in bold.

The combinations of maximum SPL and number of ANEs per night that were used during the laboratory studies are shown in table 2.2. The combinations that the subjects received during a study period were randomly assigned. As there were more combinations than exposure nights per subject,

the study design may be described as an incomplete block cross-over design.

The combinations 4x50 dB(A) and 8x50 dB(A) were not used because relevant reactions are not expected at this low level of exposure. On the other hand, the combinations 128x60 up to 128x80 dB(A), 64x70 up to 64x80 dB(A), 32x75 dB(A), 32x80 dB(A) and 16x80 dB(A) were not played back because such exposures are unrealistically high and might not have been tolerated by the subjects, or might have caused subjects to discontinue study participation ahead of schedule.

Each category was planned to consist of at least 16 subject nights, which was accomplished for all categories but 8x80 dB(A) landing. The increased number of nights with combinations 64x45 dB(A) landing and 64x65 dB(A) landing resulted from a special sub-experiment, in which both combinations were compared (see below). The number of nights with the combinations 4x55 dB(A) und 4x60 dB(A) were increased because they were just below the so called *Jansen criterion*, and thus should be covered more intensively.

The ANEs played back during the night were recorded with class-1 sound level meters (NC-10, Cortex Industries) in the vicinity of Düsseldorf Airport with closed or tilted windows. The microphone was positioned near pillow position or "at the sleeper's ear".

During a single study night always the same ANE was played back (e.g. 50 dB(A) starting only), i.e. there was no mixing of different ANE in one single night. All eight subjects of one study period received the same noise pattern, i.e. the same ANE was played back in all sleep cabins at the same time. As sound insulation in the sleep cabins was not total, a temporal offset of playback of ANEs might have lead to the perception of ANEs from neighboring sleep cabins.

From four to 128 ANEs were equidistantly played back between 11:15 pm and 6:45 am. The distance between two ANEs was 120 minutes at four events per night, 60 minutes at eight events per night, 30 minutes at 16 events per night, 15 minutes at 32 events per night, seven or eight minutes at 64 events per night and 3 or 4 minutes at 128 events per night.

As the participants did not know of the equal distances between ANEs, an anticipation of the time of occurrence of the next ANE was impossible. Watches and alarm clocks were not allowed in the sleep cabins.

Playback of ANEs was realized with an Acoustic Workstation CF85 (Cortex Industries). Before each study period, every sleep cabin was acoustically calibrated with class-1 sound level meters in order to guarantee realistic playback of ANEs.

The SPL in each sleep cabin was recorded continuously during each study night and allowed for the control of the correct playback of every ANE. Additionally, it was possible to identify loudly snoring subjects.

The subjects were only informed that the first two study nights were noise-free. They were otherwise blinded with respect to noise exposure, i.e. they did not know when, how many and what kind of ANEs were played back after the second night. In order to avoid subconscious manipulations, the investigators were also blinded for the noise pattern of the specific night. Only after the beginning of data sampling, i.e. after 11 pm, they were informed about the noise pattern of the specific night, and thus were able to monitor the correct playback of ANEs.

Altogether, 34,688 ANEs were played back in the laboratory studies. The equivalent continuous sound level [DIN] depending on the combinations of maximum SPL and number of ANEs per night are shown in table 2.3. There was a constant background noise of about 30 dB(A) in the laboratory studies caused by the air condition system.

Maximum SPL $L_{AS,max}$ in dB	Number of Noise Events Starting						Number of Noise Events Landing					
	4	8	16	32	64	128	4	8	16	32	64	128
45											**24,5** 31,0	
50			**28.0** 32.1	**31.0** 33.5	**34.0** 35.4	**37.0** 37.7			**22.7** 30.7	**25.7** 31.3	**28.7** 32.3	**31.7** 33.8
55	**25.1** 31.2	**28.1** 32.1	**31.1** 33.6	**34.1** 35.5	**37.1** 37.8	**40.1** 40.5	**21.8** 30.6	**24.7** 31.1	**27.7** 32.0	**30.7** 33.3	**33.7** 35.2	**36.7** 37.5
60	**31.7** 33.9	**34.7** 35.9	**37.7** 38.3	**40.7** 41.0	**43.7** 43.9		**26.7** 31.7	**29.5** 32.8	**32.5** 34.4	**35.5** 36.6	**38.6** 39.1	
65	**36.7** 37.5	**39.7** 40.1	**42.7** 42.9	**45.7** 45.8	**48.6** 48.6		**31.7** 33.9	**34.7** 36.0	**37.7** 38.4	**40.7** 41.1	**43.7** 43.9	
70	**41.1** 41.4	**44.1** 44.3	**47.1** 47.2	**50.2** 50.2			**36.0** 37.0	**39.0** 39.5	**42.0** 42.3	**45.1** 45.2		
75	**46.5** 46.6	**49.5** 49.6	**52.5** 52.6				**42.1** 42.3	**45.1** 45.2	**48.1** 48.2			
80	**51.5** 51.5	**54.5** 54.5					**45.6** 45.8	**48.7** 48.7				

Table 2.3: Equivalent continuous sound level $L_{AS,eq}(3)$ depending on the combinations of maximum SPL and number of ANEs per night (top and bold: aircraft noise only, bottom: aircraft noise plus constant background noise level of about 30 dB(A)).

2.2.2 Acoustics in the field studies

Both field studies STRAIN V and VI were conducted in the vicinity of Cologne/Bonn Konrad-Adenauer Airport. In the field studies, solely aircraft noise generated by air traffic at this airport was sampled, i.e. no additional ANEs were presented via loudspeakers, as was sometimes done in field studies by other investigators. A sketch of the acoustical setup is shown in figure 2.1.

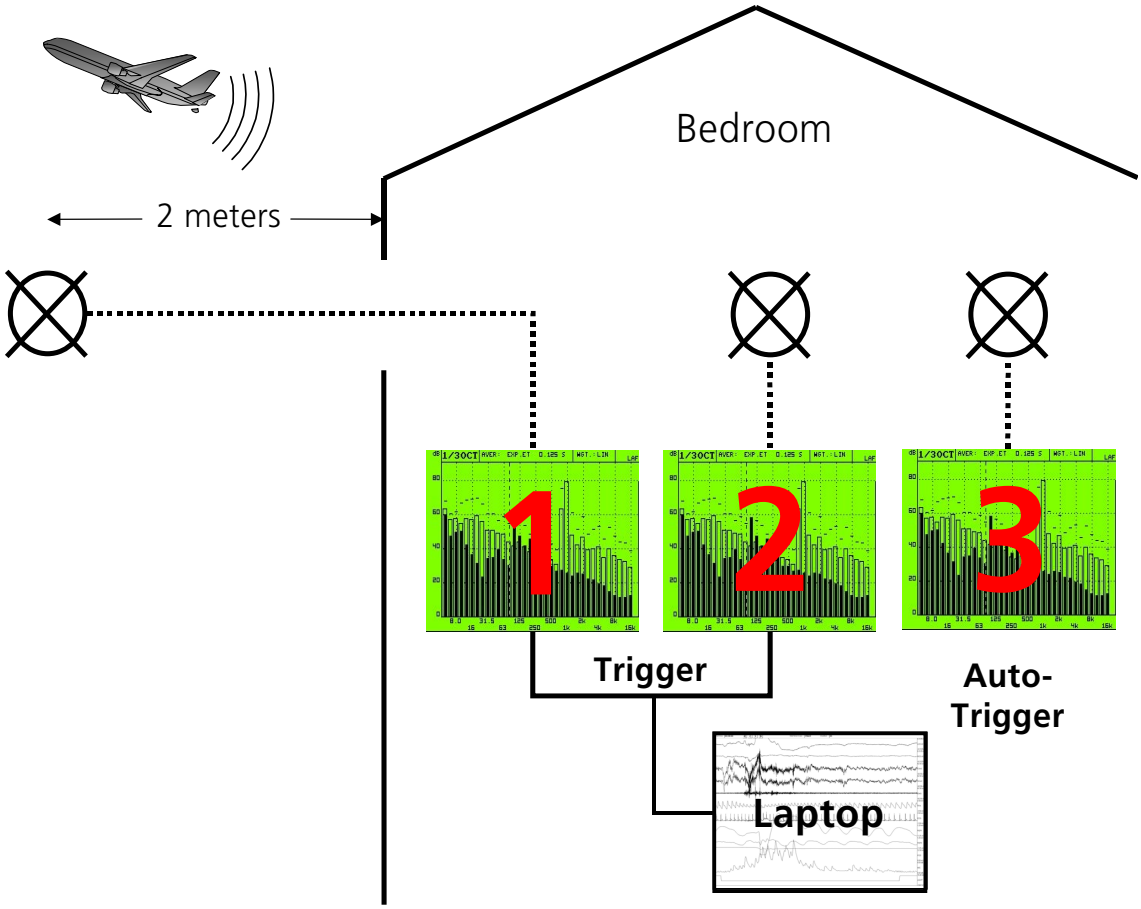

Figure 2.1: Acoustical setup of the field studies STRAIN V und VI (schematically).

Three class-1 sound level meters (NC10, Cortex Instruments) were simultaneously used. One sound level meter (#1) recorded noise events outside the bedroom with a distance of two meters to the windows, while two more sound level meters (#2 and #3) recorded noise events inside the bedroom at the sleeper's ear.

The SPLs L_{AS} and L_{lin} were continuously sampled and stored during the whole night. Once a certain background noise level (L90) was exceeded (usually by at least 4 dB), #1 recorded the actual noise event with a sampling rate of 24 kHz until the difference to the background noise level fell again below 4 dB difference to the background, but at least for 30 s. The single noise events were stored as wav-files. Hence, the identification of the noise source (e.g. aircraft, road, rail) was possible. Simultaneously, with the beginning of the recording of the noise event outside, #2 was triggered and recorded the noise event synchronously with #1, but now inside the

bedroom. A third sound level meter (#3) recorded noise events inside the bedroom as soon as a certain background noise level was exceeded (usually by at least 4 dB). In that way, it was possible to additionally identify noise events originating inside the bedroom or house (e.g. snoring) and that otherwise might have been missed, as sound level meter #2 was triggered from the outside sound level meter.

		Number of Traffic Noise Events per Night				
		≤ 25	**25-50**	**51-75**	**76-100**	**> 100**
L eq classes in dB (A)	**≤ 30**	26	37	27	15	7
	> 30-33	23	35	20	19	12
	> 33-36	16	28	45	21	14
	>36-39	9	13	19	16	19
	> 39-42	1	14	14	12	18
	>42-45		2	4	7	4
	> 45					4

Table 2.4: Number of acoustically evaluable nights during field studies with counted numbers of traffic noise events per night and the nights' corresponding Leq levels at the sleeper's ear.

2.3 Clinical chemistry

2.3.1 Laboratory studies

During laboratory studies, excretion rates of the stress hormones cortisol, adrenaline, and noradrenaline as well as of the electrolytes sodium, potassium, magnesium, and calcium were determined from two defined urine

collection periods per day. After emptying their bladders, urines of the subjects were collected daily between 7 pm and 11 pm (from arrival at AMSAN lab until going to bed), and between 11 pm and 7 am (entire night time). The beginning and the end of each collection period were taken down to the very minute. If urination during the collecting period occurred, such spontaneous urines were stored refrigerated and combined with that urine sample required at the determined time. Total volumes of the urines were determined; aliquots were deep frozen immediately in appropriate tubes, and stored until analysis at -20°C. Those 10 mL aliquots for catecholamine analyses were acidified by 200 µL 6 mol/L HCl. Longest storage time was 2 weeks, and while transported to the lab, the samples were kept deep frozen. The analyses were carried out in double assays by the renowned routine clinical laboratory of Drs Lempfrid, Lembke, Laser und partners, Cologne.

2.3.2 Field studies

During the field studies, we did not take urine samples in the evenings. Accordingly to the laboratory studies, bladder was emptied before going to bed, that time was recorded exactly, and the urine collected all night long. Next morning after wake-up, the collection period ended with the required urinating of the subject. That exact time, too, was recorded by the investigator. In the case of an urge to urinate at night, subjects were instructed to collect such additional urine within the same container, and to keep it as cool as possible in the dark until next morning.

The urines were transported immediately from the subjects' homes to the DLR institute to be processed as mentioned above, i.e. determination of total volumes and preparation of aliquots that were stored at -20°C until their final analyses in the clinical lab.

In both, laboratory and field studies no food and fluid balancing took place. Restrictions of intake existed with respect to potent substances like caffeine (e.g. coffee, tea, and cola drinks) and alcohol or to drugs that might have influenced sleep behaviour (e.g. sedatives) or might have shown cross-reactions with stress hormones (e.g. cortisone, beta-blockers). Urines taken during menstruation (visible or reported were less than 6) were discarded because of possible blood contaminations leading to false concentrations for hormones or electrolytes.

In the laboratory, dinner was offered between 7 and 8 p.m. Mineral water, herbal teas, juices, and fruit were offered *ad libitum*; sometimes salty snacks or sweets were available until going to bed. During field studies at their homes, besides of the same restrictions concerning caffeine, alcohol, or medication mentioned above, no particular food and drink pattern was requested.

2.3.3 Biochemical analyses

2.3.3.1 Electrolytes

The concentrations of sodium and potassium in urine were analyzed by ion selective electrodes (ISE method) obtained from Olympus, model AU-640. Calcium was complexed with o-cresol phthaleine, magnesium accordingly with xylidyl blue, and the coloured complexes of these electrolytes were analyzed spectral photometrically (Olympus Diagnostica, Hamburg). Calibrators and standards were also purchased from Olympus Diagnostica.

2.3.3.2 Catecholamines

Samples for adrenaline and noradrenaline determinations were analyzed by high performance liquid chromatography (HPLC) and electrochemical detector. The analyzing system, controls, and calibrators were from Chromsystems, Munich.

2.3.3.3 Cortisol

Free cortisol concentrations from the urines were measured by a radio immuno assay (RIA) from DPC Biermann. The cortisol samples of study phase STRAIN II (32 subjects) exclusively, were measured by a solid phase chemo luminescence enzyme immuno assay (LEIA) with an Immulite 2000 from DPC Biermann, as in the meantime, since the analysis of urine samples from study phase STRAIN I the clinical lab had given up the RIA method, temporarily in favour of the LEIA one due to delivery problems. Unfortunately, we had no knowledge beforehand of that change of methods. Controls for free cortisol were from Chiron Diagnostics.

2.4 Statistics

A mixed model (PROC MIXED in SAS, Version 8.2) was used for the analysis of the data. Subject effects were considered random because the subjects in the experiment were only a small subset of a larger set of eligibles over which inference about exposure means was to be made. Therefore, the mixed model also accounted for the fact that single subjects were investigated repeatedly over several nights, i.e. non-independency of data. Additionally, a major advantage of using a mixed model was that information on differences both within subjects and between subjects was utilised [Olofsen et al. 2004]. In contrast to standard ANOVA techniques, mixed models are able to cope with missing data to some extent. Statistical significance was assumed at $p < 0.05$. If the results of the analysis indicated that the estimate of at least one main effect level differed from the overall mean ($p < 0.05$), differences between each exposure pattern and the baseline night were calculated and tested for significant deviances from zero post-hoc. Dunnett's method was used for multiple comparison adjustments of p-values and confidence limits, using the factor-analytic covariance approximation [Hsu 1992]. Tested were excretion rates of investigated stress hormones and electrolytes with the noise level at the sleeper's ear represented in the lab by equivalent sound pressure level L_{eq}, by maximum

sound pressure level $L_{AS,max}$, and the frequency (number of aircraft noise events (ANE) per night) of the according noise level. In the field study the excretion rates were compared only with L_{eq} during time in bed of the subjects and the number of traffic noise events per night. Maximum SPLs were often masked by various other noise sources like turning over in bed, coughing or snoring of the partner, street noise or bird songs etc. Such noise events occurred quite often during the nights, and even louder than many aircraft noises measured indoors. In the case of stress hormones, additional statistical analyses were run on possible influences by gender, age, noise sensitivity or pre-annoyance level to aircraft noise on excretion rates. Finally, the results of those 20 subjects who had participated in both laboratory and field study were statistically scrutinized. Univariable mixed model regression analyses with random subject effect were run for all variables, and in the case of noradrenaline and cortisol they were additionally adjusted for age, gender, and noise sensitivity. Unfortunately, with a single point measure, i.e. one urine sample only during the entire night, event correlated analysis is impossible.

Originally, for statistical purposes SPSS (version 11.5) had been used, since the SAS mixed model methods were not yet available to us. SPSS methods applied firstly were non-parametric Wilcoxon-tests and Mann-Whitney U-tests as well as trend tests (Jonckheere-Terpstra). These ranking tests, however, are less sensitive tools in comparison to the mixed model. They neglect for instance, the multiple measures of individuals.

3 Results

During the laboratory studies, 1664 urine samples were collected both in the evening hours and once more at night, whereas 576 just nocturnal urine samples were collected during the field studies omitting evening samples. From all samples the corresponding parameters were measured. About 99% were evaluated. Those very rare cases of e.g. anuria, blood intermixture during menstruation or accidental urination into the toilet were disregarded or lost. The total number of cases with data loss was in the laboratory 17 during evening collections, 14 during night collections, and 8 in the field studies, when exclusively night urines were analysed. Additional loss occurred when the necessary corresponding acoustical data were missing e.g. due to storms, microphone failures etc. (16 nights out of 64*8 nights) resulting in findings that were not interpretable.

L_{eq} classes are set up in steps of 3 dB. $L_{eq} \leq 30$ dB was the threshold for noise free nights in the laboratory, when no aircraft noise was applied, and just the background humming of the air conditioning caused some artificial noise. This L_{eq} class serves as baseline. In accordance the same limit is used in the field studies as reference. All SPLs given in dB are A weighted.

Whereas in the laboratory studies maximum L_{eq} levels of up to 54.5 dB occurred, in the field only 21 nights (see Table 2.4) showed L_{eq} levels of > 42 dB. Thus for laboratory results all nights with L_{eq} >51 dB, and for field results L_{eq} > 39 dB are combined within a single L_{eq} class only.

In general, night #2 serves as baseline or reference, respectively, since the first night is regarded as an adaptation night to the new environment and/or instrumentation.

3.1 Electrolytes

3.1.1 Sodium

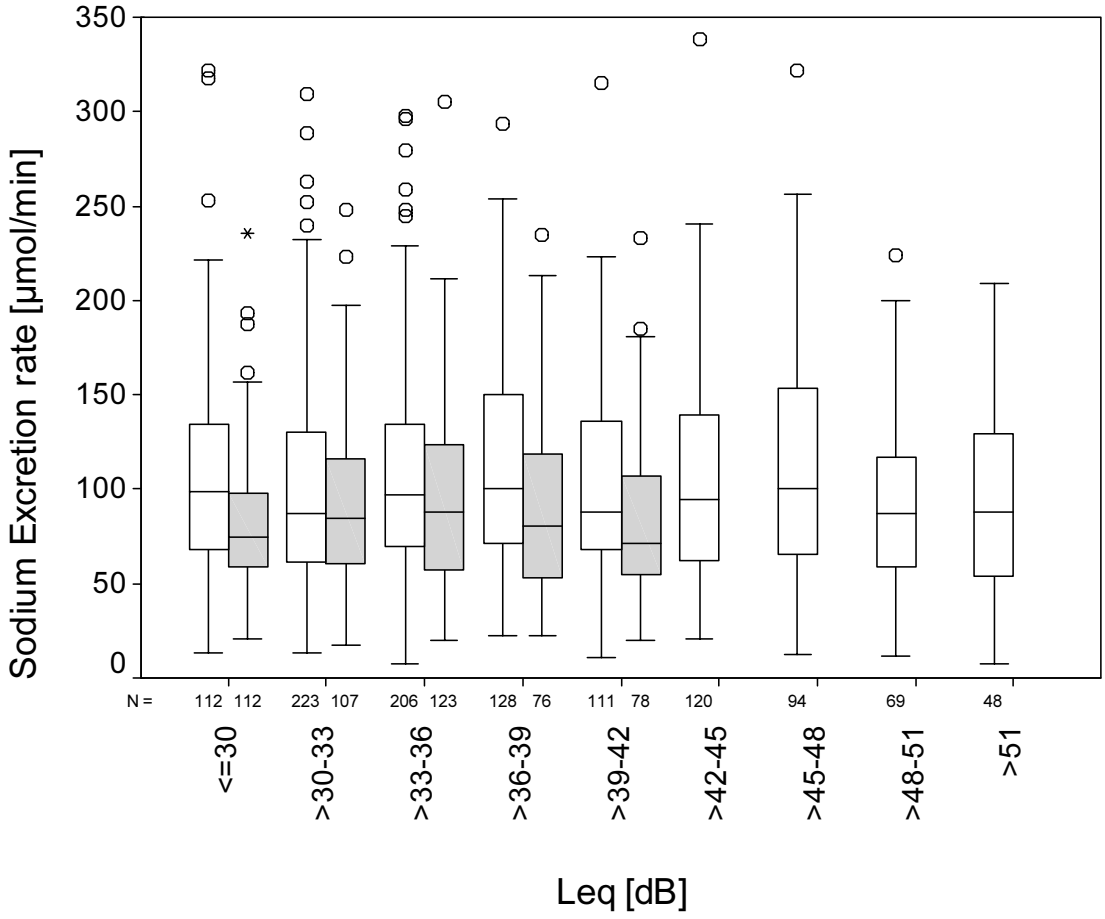

Figure 3.1: Box plot of the sodium excretion rates in all night urine samples during both laboratory (light boxes) and field (grey boxes) studies depending on L_{eq} classes during the nights. Laboratory studies comprise experimental groups only, nights 2 - 11, field studies nights 2 - 9. N refers to the number of investigated nights.

Figure 3.1 shows the box plots[1] of nocturnal urinary sodium excretion rates depending on the L_{eq} level during the nights. Shown are the results of the experimental groups in the laboratory without nights 1, 12, and 13 having been adaptation and recovery nights without aircraft noise. Baseline night 2 was also noise free (≤ 30 dB). The results are given in light boxes. The results from the field studies are indicated in grey boxes. Here, the first night is omitted as adaptation night.

Normal range for sodium excretion in urine (adults, ISE method) is 19 – 200 µmol/min [calculated from 24h excretion, Tietz 1995].

The F-test applied to the data of the laboratory experimental group of 112 subjects shows that there is no significant difference in sodium excretions during baseline nights compared to pooled data of noisy nights ($F = 0.64$ and $p = 0.424$). The mixed model estimates for sodium excretions during the baseline nights a mean ± SE = 107.2 ± 5.1 µmol/min and for the pooled data of noisy nights a mean ± SE = 104.3 ± 3.9 µmol/min. A univariable regression analysis indicates a statistically non significant and irrelevant decrease of the sodium excretion rate depending on L_{eq} ($p = 0.560$; -0.1 µmol/min per 1 dB increase L_{eq}).

The F-test applied to the data of the field group of 64 subjects states that there is no significant difference in sodium excretions during reference nights with an $L_{eq} \leq 30$ dB compared to pooled data of nights with $L_{eq} > 30$ dB ($F = 0.94$ and $p = 0.333$). The mixed model estimates for sodium excretions during the quiet nights a mean ± SE = 85.6 ± 5.6 µmol/min and for the pooled data of nights with $L_{eq} > 30$ dB a mean ± SE = 90.4 ± 4.3 µmol/min. A univariable regression analysis indicates a statistically non significant and irrelevant increase of the sodium excretion rate depending on L_{eq} ($p = 0.672$; 0.2 µmol/min per 1 dB increase L_{eq}).

[1]Box plots according to Tukey [1977] show the mean 50% of the distribution with the upper line of the box representing the limit of the 3rd quartile, and the lower the 1st quartile. The mean horizontal line shows the median. Vertical lines above and below the boxes indicate that area where results have been obtained if lying within the 1.5-fold interquartile range (i.e. the range between 1st and 3rd quartiles) maximum. Every outlier up to 3-fold of the interquartile range is marked by a circle, any higher deviation by an asterisk.

There is a significant difference between nocturnal sodium excretion rates in the laboratory and the field, where the rates are lower ($F = 7.17$ and $p = 0.008$). The estimated mean excretion rates are in the laboratory studies ± SE = 104.8 ± 3.3 µmol/min, and estimated mean in the field studies ± SE = 89.0 ± 4.8 µmol/min.

The box plots of Figure 3.2 and Figure 3.3 indicate the nocturnal sodium excretion rates in the laboratory studies with both increasing SPLs and increasing numbers of ANEs. The mixed model regression analysis (Table 3.1) indicates a statistically non significant and irrelevant influence of the number of ANEs and the maximum SPL on sodium excretion. There is no significant interaction between ANE and SPL ($p = 0.657$).

Variable	**β**	**p-value**
Maximum SPL	0.02832	0.851
Number of ANE	0.04548	0.277

Table 3.1: Mixed model regression calculation of nocturnal sodium excretion rates and its statistical dependency on maximum SPL and number of ANE.

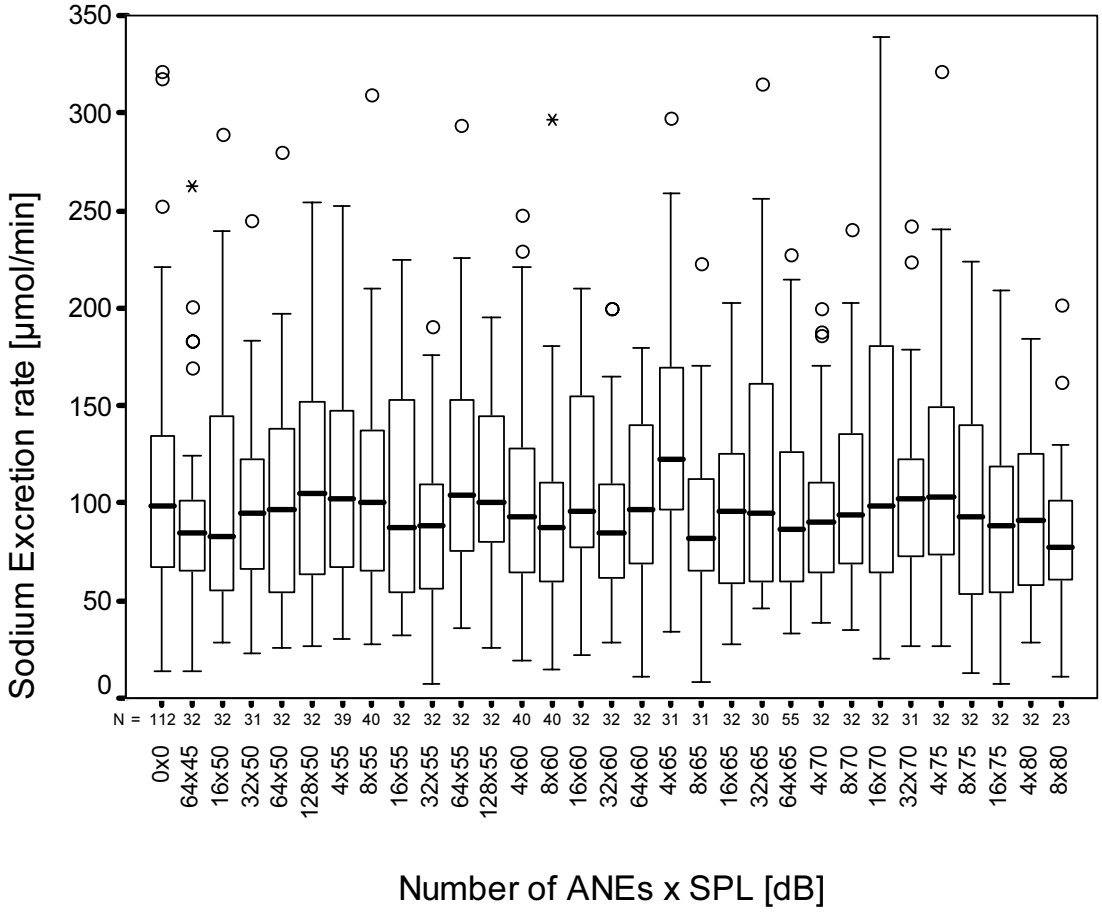

Figure 3.2: Box plot of the sodium excretion rates in all night urine samples during laboratory studies depending on increasing numbers of aircraft noise events (ANE) and corresponding SPL during the nights. Laboratory studies comprise experimental groups only, with nights 2 – 11. N refers to the number of investigated nights.

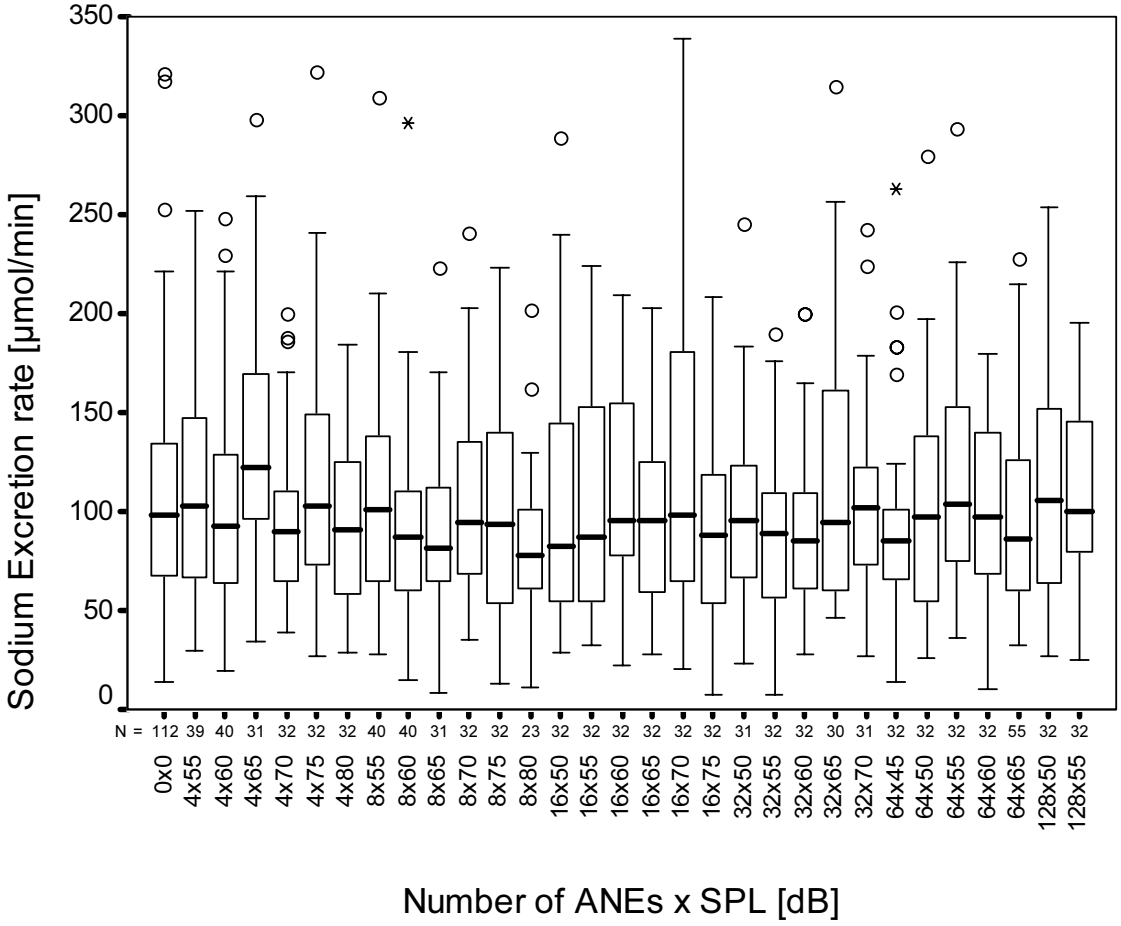

Figure 3.3: Box plot of the sodium excretion rates in all night urine samples during laboratory studies depending on number of aircraft noise events (ANE) and corresponding increasing SPL during the nights. Laboratory studies comprise experimental groups only with nights 2 – 11. N refers to the number of investigated nights.

Table 3.2 illustrates in detail the statistical evaluation of sodium excretion rates and their dependency on all combinations of maximum SPL and number of ANE per night. According to mixed model calculations none of the exposure nights differs significantly from the noise free baseline nights.

Maximum SPL LAS,max in dB	Number of Aircraft Noise Events per night					
	4	**8**	**16**	**32**	**64**	**128**
45					98.7±7.7 p=1.000	
50			109.5±7.8 p=1.000	100.1±7.9 p=1.000	94.5±7.8 p=0.914	118.8±7.8 p=0.969
55	105.2±7.3 p=1.000	102.2±7.2 p=1.000	98.3±7.8 p=0.999	101.4±7.8 p=1.000	109.3±7.7 p=1.000	112.4±7.8 p=1.000
60	112.4±7.2 p=1.000	101.3±7.3 p=1.000	97.7±7.8 p=0.998	100.0±7.8 p=1.000	94.4±7.8 p=0.909	
65	124.4±7.9 p=0.499	99.5±7.8 p=1.000	102.3±7.8 p=1.000	116.6±8.0 p=0.999	102.6±6.3 p=1.000	
70	110.0±7.8 p=1.000	96.3±7.8 p=0.984	111.6±7.8 p=1.000	104.7±7.9 p=1.000		
75	108.0±7.8 p=1.000	98.3±7.8 p=0.992	106.7±7.8 p=1.000			
80	100.9±7.8 p=1.000	86.7±8.9 p=0.396				

Table 3.2: Estimated mean sodium excretion rates (± SE) [µmol/min] in all night urine samples during **experimental** laboratory studies (n = 112) depending on all combinations of maximum SPL and number of ANEs per night applied and their corresponding adjusted p-values with noise free (0x0) night # 2 (estimated mean ± SE = 107.2 ± 5.1 µmol/min) serving as reference.

Figure 3.4 illustrates the sodium excretion rates at night during field studies in dependency on the number of traffic noise events per night. None of the exposure categories differs statistically significantly from the overall mean ($F = 1.20$ and $p = 0.317$). There is no dose-response relationship. The mixed model regression analysis (Table 3.3) indicates a statistically non significant and irrelevant influence of the number of traffic noise events per night and L_{eq} on the sodium excretion. There is no significant interaction between L_{eq} and number of traffic noise events ($p = 0.460$).

Variable	β	p-value
Leq	0.22250	0.668
Number of Traffic Noise Events per Night	-0.00344	0.942

Table 3.3: Mixed model regression calculation of nocturnal sodium excretion rates and its statistical dependency on Leq and number of traffic noise events per night.

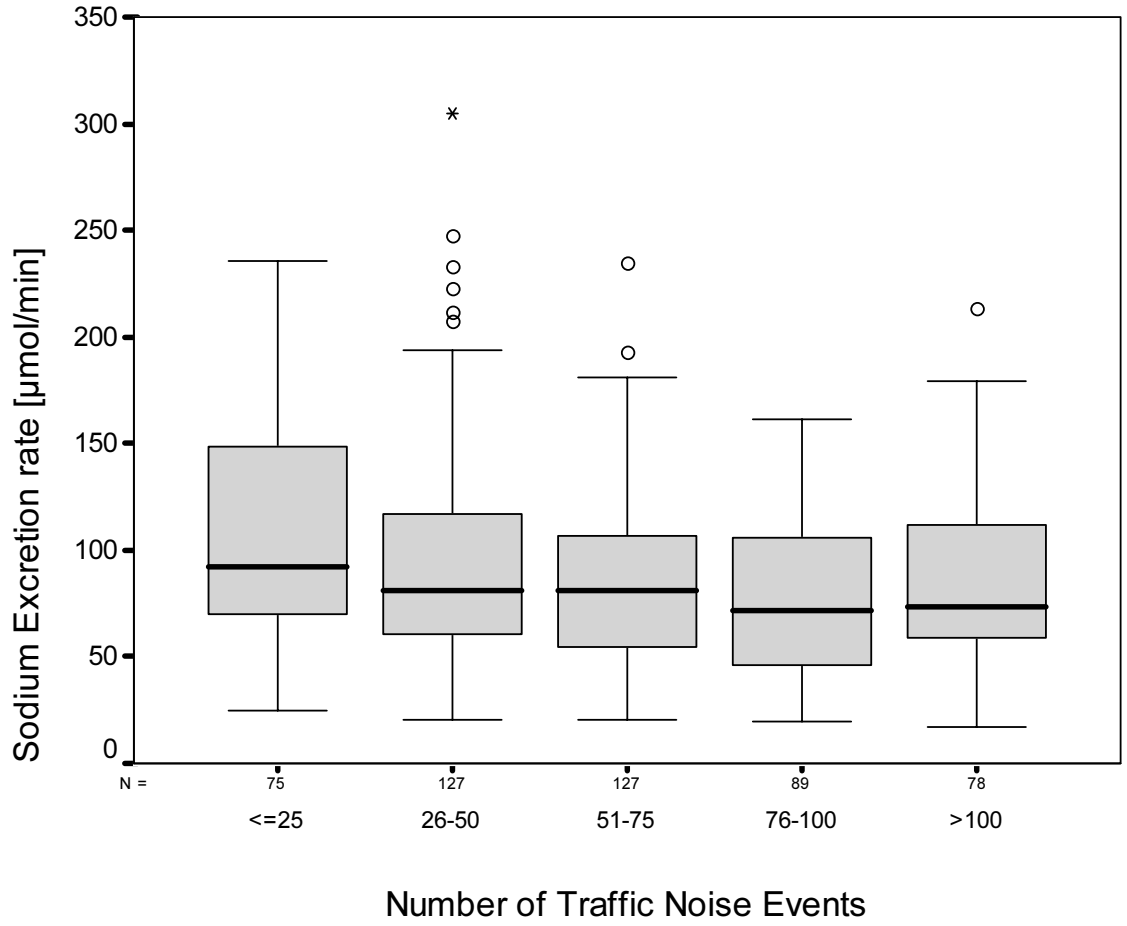

Figure 3.4: Box plot of the sodium excretion rates in all night urine samples during field studies depending on number of traffic noise events during the nights. Field studies comprise all nights 2 – 9. N refers to the number of investigated nights.

Figure 3.5 and Figure 3.6 show in box plots the sodium excretion rates in the laboratory studies comparing experimental and control groups, as well as in the field studies in dependency on the experimental night. In the con-

trol group, none of the exposure nights 1 – 13 differs statistically significantly from the overall mean (F-test: $F = 1.49$ and $p = 0.132$).

In the laboratory experimental group, the result of the F-test indicates that at least one of the experiment nights differs statistically significantly from the overall mean ($F = 4.73$ and $p < 0.001$). Post-hoc tests shown in Table 3.4 reveal that the sodium excretion rate during night #8 (93.4 ± 5.0 µmol/min) is significantly lower than that one during reference night #2 (107.2 ± 5.0 µmol/min). None of the other nights, including adaptation, recovery, and last night, differs significantly from the reference night.

In the field group, the result of the F-test indicates that at least one of the experimental nights differs statistically significantly from the overall mean ($F = 2.93$ and $p = 0.003$). Post-hoc tests shown in Table 3.5 reveal that the sodium excretion rate during night #3 (96.1 ± 5.8 µmol/min) is significantly higher than that one during reference night #2 (78.7 ± 5.8 µmol/min). None of the other nights, including adaptation and last night, differs significantly from the reference night.

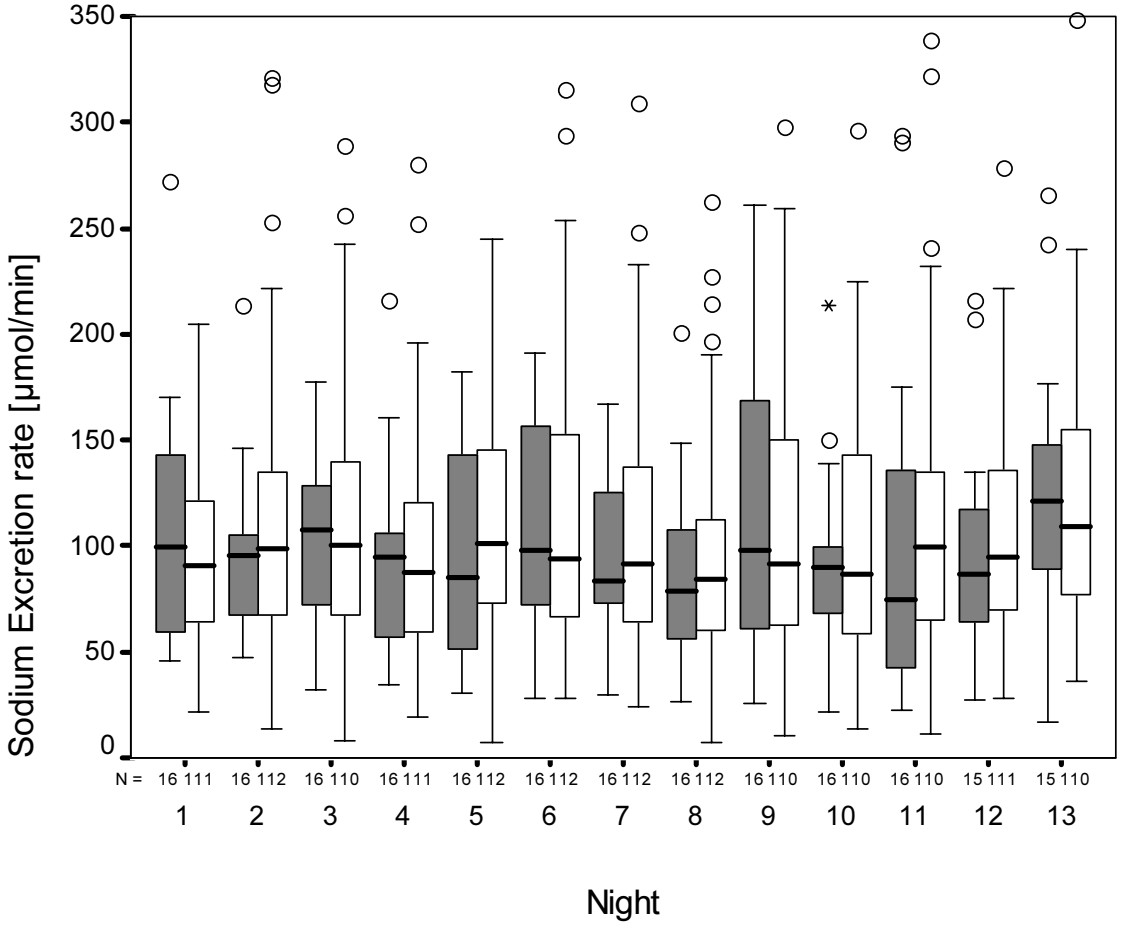

Figure 3.5: Box plot of the sodium excretion rates in all night urine samples in both control group (grey boxes, 16 subjects) and experimental group (light boxes, 112 subjects) during the laboratory studies depending on the consecutive experimental nights. First nights were always Monday/Tuesday nights. N refers to the number of investigated nights.

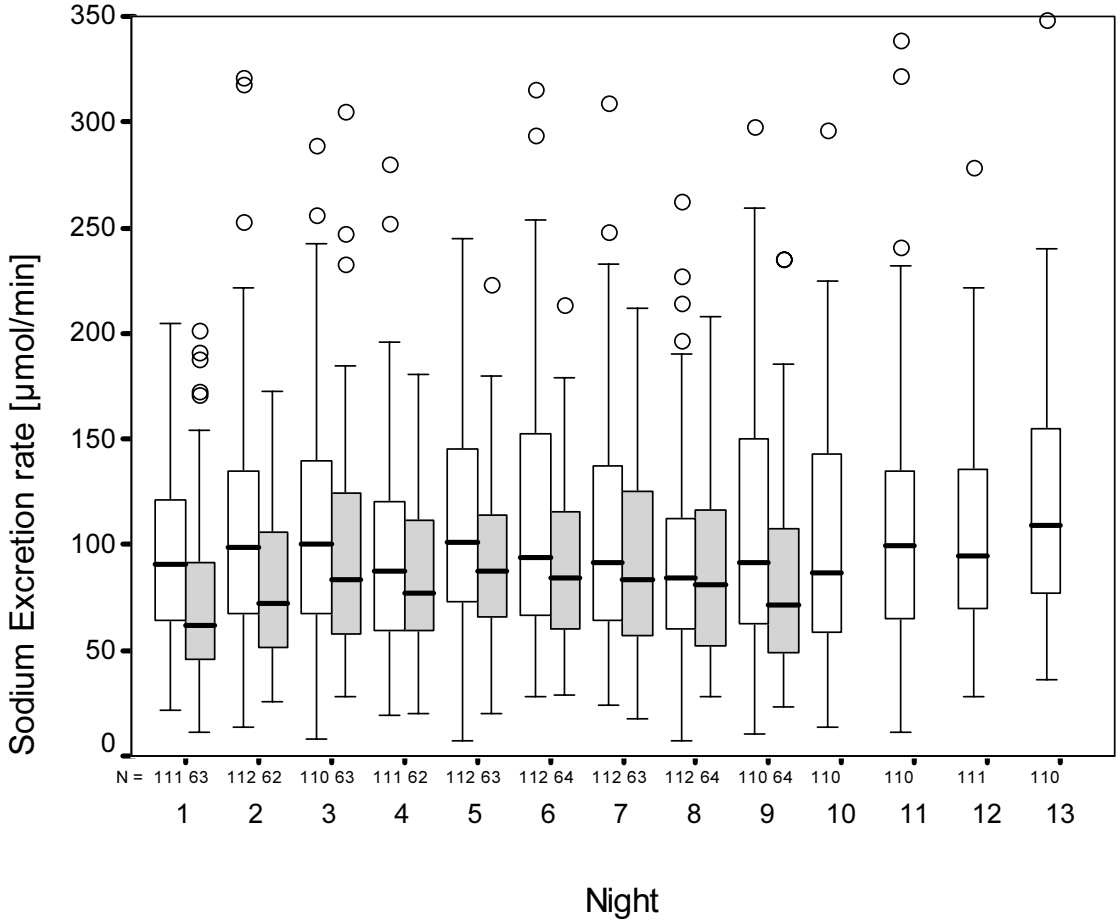

Figure 3.6: Box plot of the sodium excretion rates in all night urine samples in both experimental group during laboratory studies (light boxes, 112 subjects) and field studies (grey boxes, 64 subjects) depending on the consecutive experimental nights. First nights were always Monday/Tuesday nights. N refers to the number of investigated nights.

Night	Estimated mean ± SE [µmol/min]	Adjusted p-value
Night #1	97.1 ± 5.0	0.250
Night #2	107.2 ± 5.0	Reference
Night #3	110.1 ± 5.0	0.999
Night #4	94.7 ± 5.0	0.082
Night #5	111.3 ± 5.0	0.985
Night #6	112.1 ± 5.0	0.952
Night #7	103.5 ± 5.0	0.993
Night #8	93.4 ± 5.0	**0.040**
Night #9	104.5 ± 5.0	1.000
Night #10	102.1 ± 5.0	0.931
Night #11	106.6 ± 5.0	1.000
Night #12	105.4 ± 5.0	1.000
Night #13	120.3 ± 5.0	0.063

Table 3.4: Estimated mean sodium excretion rates (± SE) in all night urine samples during laboratory studies, experimental group (n = 112) depending on experimental night and their corresponding adjusted p-values with night #2 serving as reference. Significance $p < 0.05$ in bold.

Night	Estimated mean ± SE [µmol/min]	Adjusted p-value
Night #1	75.3 ± 5.8	0.996
Night #2	78.7 ± 5.8	Reference
Night #3	96.1 ± 5.8	**0.030**
Night #4	85.4 ± 5.8	0.829
Night #5	92.6 ± 5.8	0.129
Night #6	93.2 ± 5.7	0.100
Night #7	94.9 ± 5.8	0.051
Night #8	89.1 ± 5.7	0.395
Night #9	83.8 ± 5.7	0.951

Table 3.5: Estimated mean sodium excretion rates (± SE) in all night urine samples during field studies (n = 64) depending on experimental night and their corresponding adjusted p-values with night #2 serving as reference. Significance $p < 0.05$ in bold.

3.1.2 Potassium

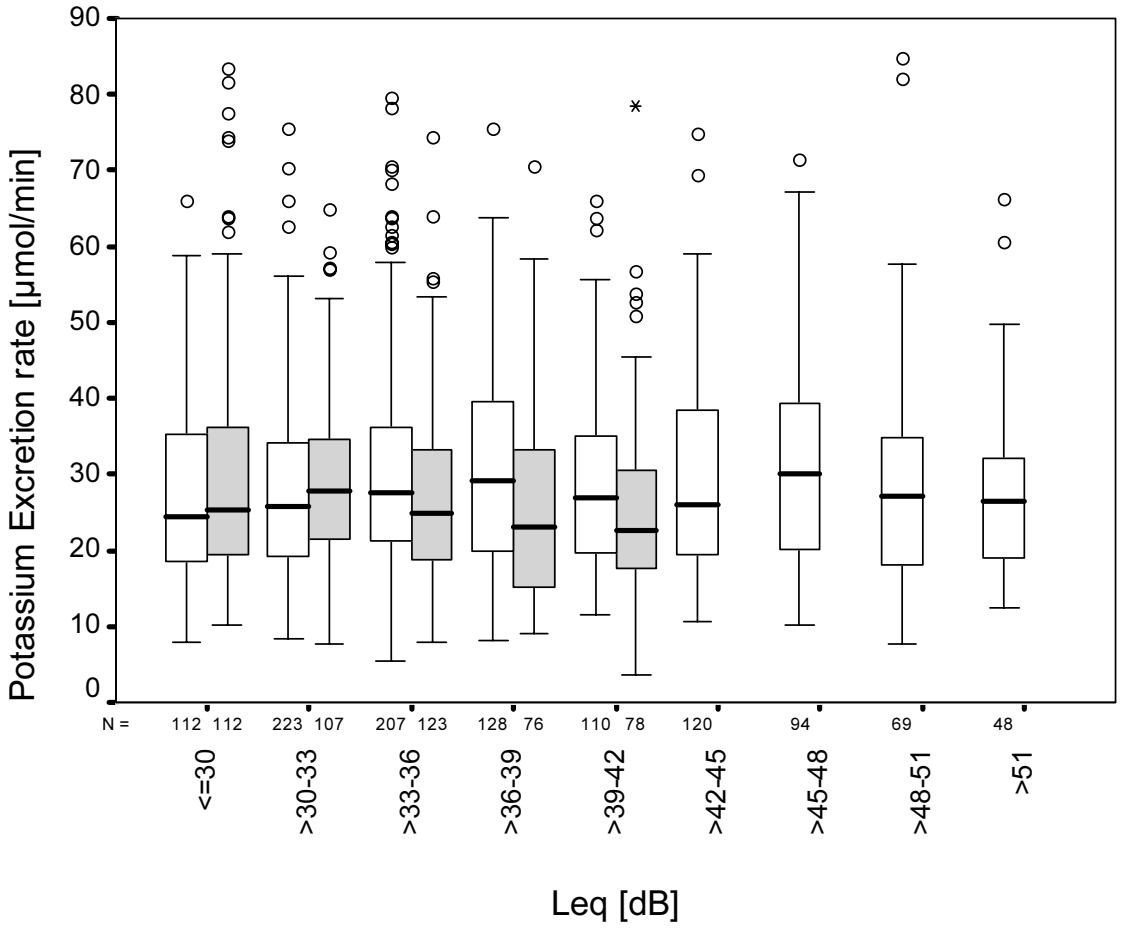

Figure 3.7: Box plot of the potassium excretion rates in all night urine samples during both laboratory (light boxes) and field (grey boxes) studies depending on L_{eq} classes during the nights. Laboratory studies comprise experimental groups only, with nights 2 – 11, field studies with nights 2 - 9. N refers to the number of investigated nights.

Figure 3.7 shows the box plots of nocturnal urinary potassium excretion rates depending on the L_{eq} level during the nights. Shown are the results of the experimental groups in the laboratory without nights 1, 12, and 13 having been adaptation and recovery nights without aircraft noise. Baseline night 2 was also noise free (≦ 30 dB). The results are given in light boxes. The results from the field studies are indicated in grey boxes. Here, the first night is omitted as adaptation night.

Normal range for potassium excretion in urine (adults, ISE method) is 17 – 87 µmol/min [calculated from 24h excretion, Tietz 1995].

The F-test applied to the data of the laboratory experimental group of 112 subjects shows that at least one of the Leq classes differs statistically significantly from the potassium excretion during baseline nights (F = 8.53 and p = 0.004). Post-hoc tests shown in Table 3.6 reveal that the potassium excretion rates in Leq classes >36 - 39 dB (30.7 ± 1.2 µmol/min) and >42 - 45 dB (28.9 ± 1.2 µmol/min) are significantly higher than in the baseline group Leq ≤ 30 dB. The mixed model estimates for potassium excretions during the baseline nights a mean ± SE = 26.6 ± 1.2 µmol/min and for the pooled data of noisy nights a mean ± SE = 29.4 ± 0.9 µmol/min. A univariable regression analysis indicates a statistically non significant and irrelevant increase of the potassium excretion rate depending on Leq (p = 0.529; 0.03 µmol/min per 1 dB increase Leq).

The F-test applied to the data of the field group of 64 subjects states that there is no significant difference in potassium excretions during reference nights with an Leq ≤ 30 dB compared to pooled data of nights with Leq > 30 dB (F = 1.30 and p = 0.254) The mixed model estimates for potassium excretions during the quiet nights a mean ± SE = 28.9 ± 1.6 µmol/min and for the pooled data of nights with Leq > 30 dB a mean ± SE = 27.4 ± 1.3 µmol/min. A univariable regression analysis indicates a statistically non significant and irrelevant decrease of the potassium excretion rate depending on Leq (p = 0.947; -0.009 µmol/min per 1 dB increase Leq).

There is no significant difference between nocturnal potassium excretion rates in the laboratory and the field (F = 0.88 and p = 0.350). The estimated mean excretion rates are in the laboratory studies ± SE = 29.0 ± 0.8 µmol/min, and in the field studies ± SE = 27.6 ± 1.2 µmol/min.

Leq classes	Estimated mean ± SE [µmol/min]	Adjusted p-value
≤ 30 dB	26.6 ± 1.2	Reference
>30-33 dB	29.2 ± 1.1	0.165
>33-36 dB	28.9 ± 2.0	0.296
>36-39 dB	30.7 ± 1.2	**0.012**
>39-42 dB	29.3 ± 1.3	0.272
>42-45 dB	28.9 ± 1.2	**0.009**
>45-48 dB	31.1 ± 1.3	0.658
>48-51 dB	28.8 ± 1.5	0.612
> 51 dB	29.6 ± 2.0	0.990

Table 3.6: Estimated mean potassium excretion rates (± SE) in all night urine samples during laboratory studies depending on Leq classes during these nights, and their corresponding adjusted p-values with Leq class ≤ 30 dB serving as reference. Significance $p < 0.05$ in bold.

The box plots of Figure 3.8 and Figure 3.9 indicate the nocturnal potassium excretion rates in the laboratory studies with both increasing SPLs and increasing numbers of ANEs. The mixed model regression analysis (Table 3.7) indicates a statistically non significant and irrelevant influence of the number of ANEs and the maximum SPL on the potassium excretion. There is no significant interaction between ANE and SPL ($p = 0.647$).

Variable	β	p-value
Maximum SPL	0.03490	0.385
Number of ANE	0.01723	0.128

Table 3.7: Mixed model regression calculation of nocturnal potassium excretion rates and its statistical dependency on maximum SPL and number of ANE.

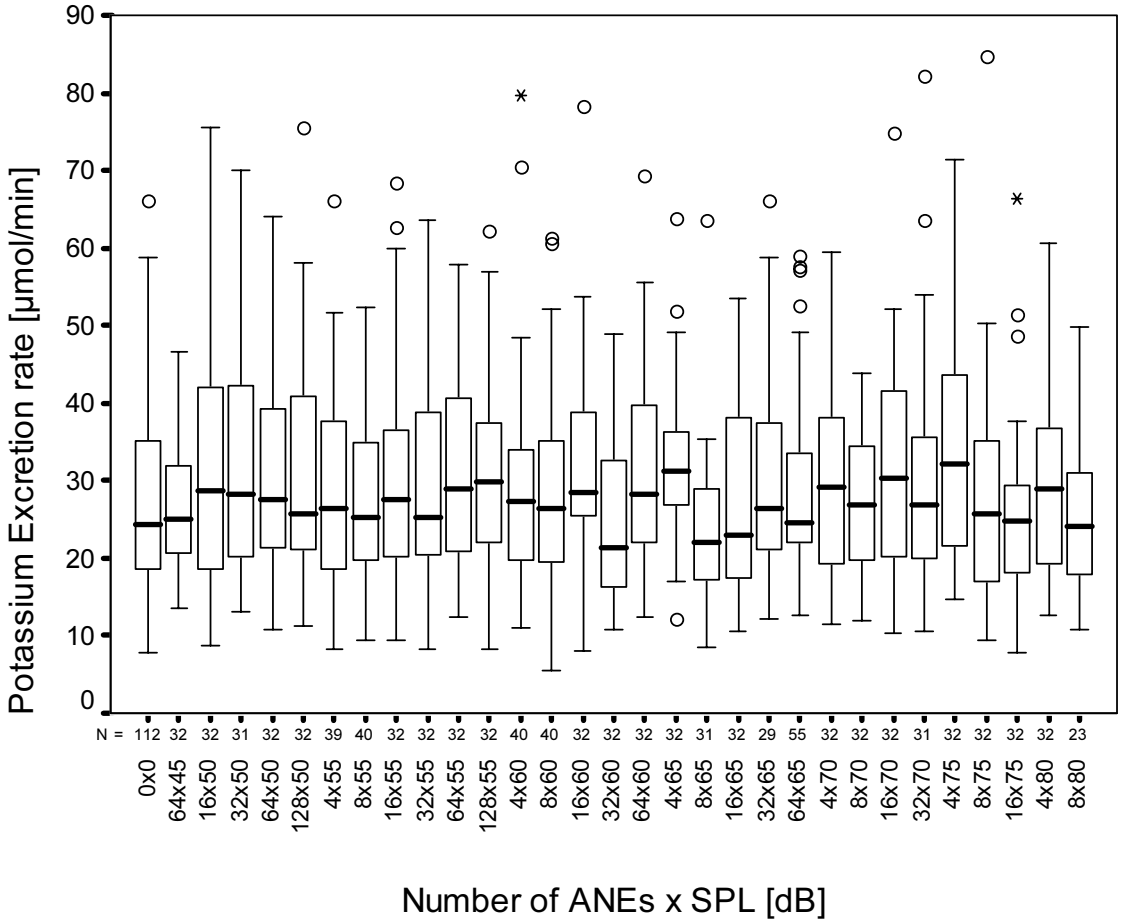

Figure 3.8: Box plot of the potassium excretion rates in all night urine samples during laboratory studies depending on increasing numbers of aircraft noise events (ANE) and corresponding SPL during the nights. Laboratory studies comprise experimental groups only, with nights 2 – 11. N refers to the number of investigated nights.

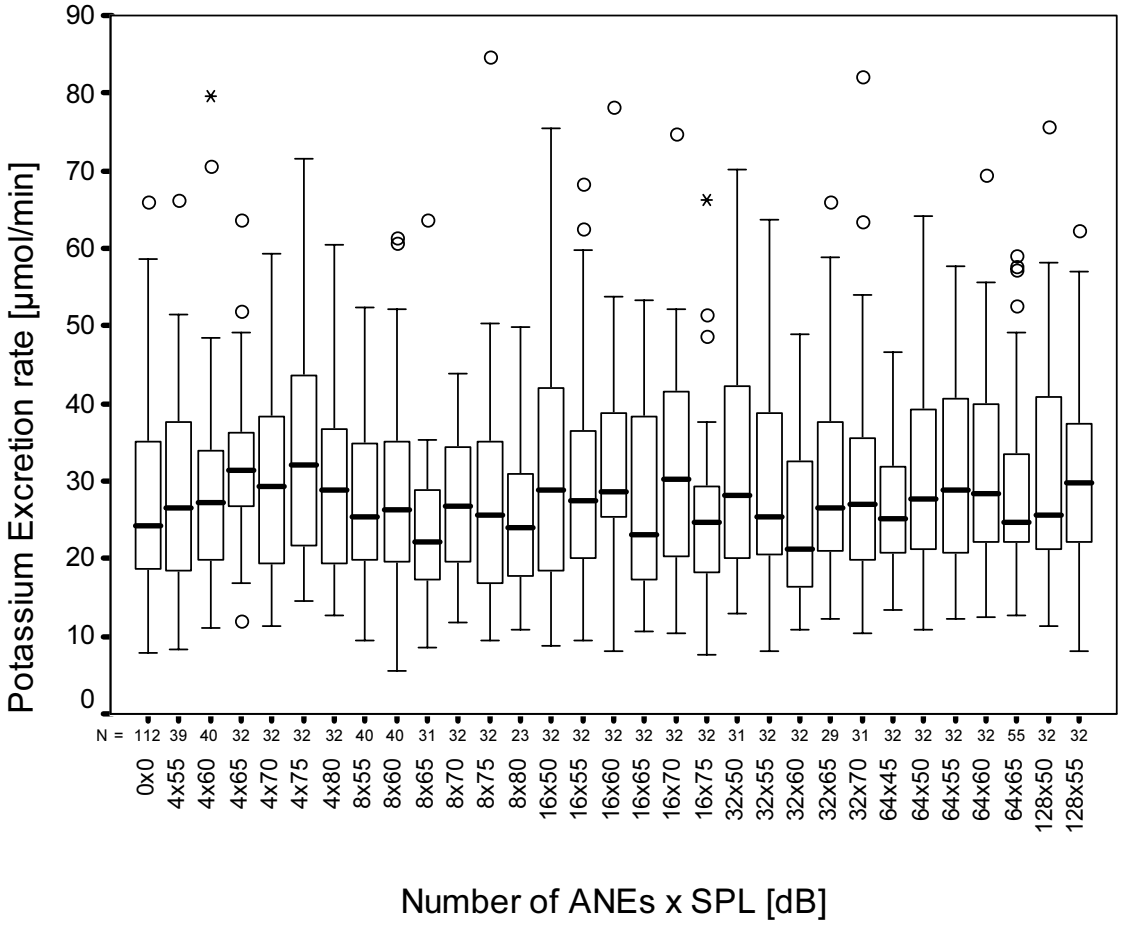

Figure 3.9: Box plot of the potassium excretion rates in all night urine samples during laboratory studies depending on number of aircraft noise events (ANE) and corresponding increasing SPL during the nights. Laboratory studies comprise experimental groups only with nights 2 – 11. N refers to the number of investigated nights.

Table 3.8 illustrates in detail the statistical evaluation of potassium excretion rates and their dependency on all combinations of maximum SPL and number of ANE per night. According to mixed model calculations potassium excretion rates are significantly higher than the baseline rate (26.6 ± 1.2 µmol/min) in 12 out of 30 combinations.

Maximum SPL LAS,max in dB	Number of Aircraft Noise Events per night					
	4	**8**	**16**	**32**	**64**	**128**
45					29.7±1.9 p=0.124	
50			**30.9±1.9** **p=0.031**	**31.3±2.0** **p=0.019**	27.6±2.0 p=0.621	**31.5±2.0** **p=0.014**
55	29.1±1.8 p=0.182	27.0±1.8 p=0.841	28.4±2.0 p=0.379	30.1±2.0 p=0.082	28.6±1.9 p=0.315	**32.2±1.9** **p=0.005**
60	29.2±1.8 p=0.157	29.1±1.8 p=0.184	**31.0±2.0** **p=0.027**	26.8±2.0 p=0.939	29.1±2.0 p=0.204	
65	**31.2±2.0** **p=0.021**	24.4±2.0 p=0.268	26.9±2.0 p=0.891	29.8±2.0 p=0.122	**30.0±1.6** **p=0.037**	
70	**32.8±2.0** **p=0.002**	25.9±1.9 p=0.728	**31.5±1.9** **p=0.014**	**31.2±2.0** **p=0.022**		
75	**33.9±1.9** **p=0.001**	28.9±2.0 p=0.261	27.6±2.0 p=0.635			
80	**30.5±1.9** **p=0.049**	26.5±2.2 p=0.951				

Table 3.8: Estimated mean potassium excretion rates (± SE) [µmol/min] in all night urine samples during **experimental** laboratory studies (n = 112) depending on all combinations of maximum SPL and number of ANEs per night applied and their corresponding adjusted p-values with noise free (0x0) night # 2 (estimated mean ± SE = 26.6 ± 1.2 µmol/min) serving as reference. Significance $p < 0.05$ in bold.

Figure 3.10 illustrates the potassium excretion rates at night during field studies in dependency on the number of traffic noise events per night. None of the exposure categories differs statistically significantly from the overall mean ($F = 0.57$ and $p = 0.685$). There is no dose-response relationship. The mixed model regression analysis (Table 3.9) indicates a statistically non significant and irrelevant influence of the number of traffic noise events per night and L_{eq} on the potassium excretion. There is no significant interaction between L_{eq} and number of traffic noise events ($p = 0.521$).

Variable	β	p-value
Leq	0.00039	0.998
Number of Traffic Noise Events per Night	-0.00539	0.675

Table 3.9: Mixed model regression calculation of nocturnal potassium excretion rates and its statistical dependency on Leq and number of traffic noise events per night.

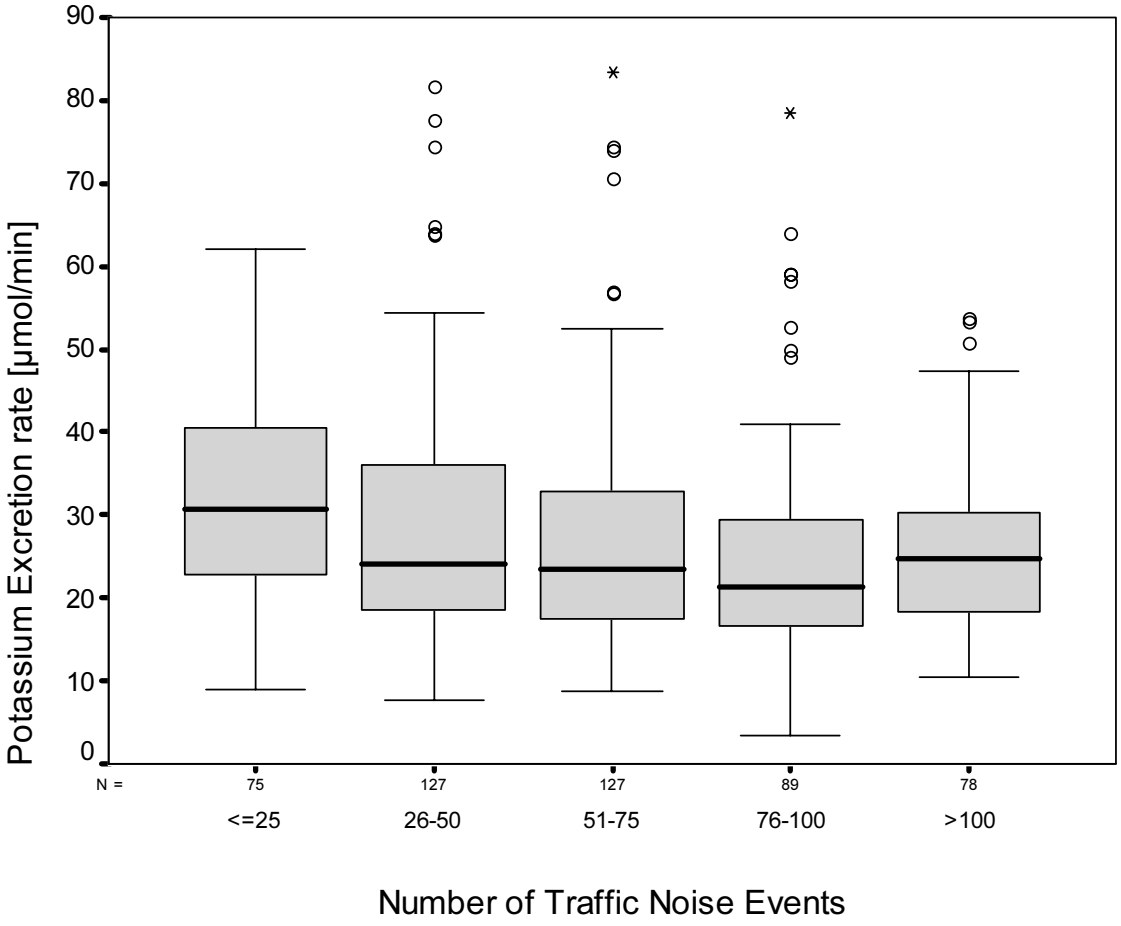

Figure 3.10: Box plot of the potassium excretion rates in all night urine samples during field studies depending on number of traffic noise events during the nights. Field studies comprise nights 2 – 9. N refers to the number of investigated nights.

Figure 3.11 and Figure 3.12 show in box plots the potassium excretion rates in the laboratory studies comparing experimental and control groups, as well as in the field studies in dependency on the experimental night. In the control group, none of the exposure nights 1 – 13 differs statistically significantly from the overall mean (F-test: $F = 0.99$ and $p = 0.458$).

In the laboratory experimental group, the result of the F-test indicates that at least one of the experiment nights differs statistically significantly from the overall mean ($F = 10.04$ and $p < 0.001$). Post-hoc tests shown in Table 3.10 reveal that the potassium excretion rates during nights #5, #8 , #9, #11, #12 and #13 are significantly higher than that one during reference night #2 (26.6 ± 1.2 µmol/min). None of the other nights differs significantly from the reference night.

In the field group, the result of the F-test indicates that none of the experiment nights differs statistically significantly from the overall mean ($F = 1.61$ and $p = 0.119$).

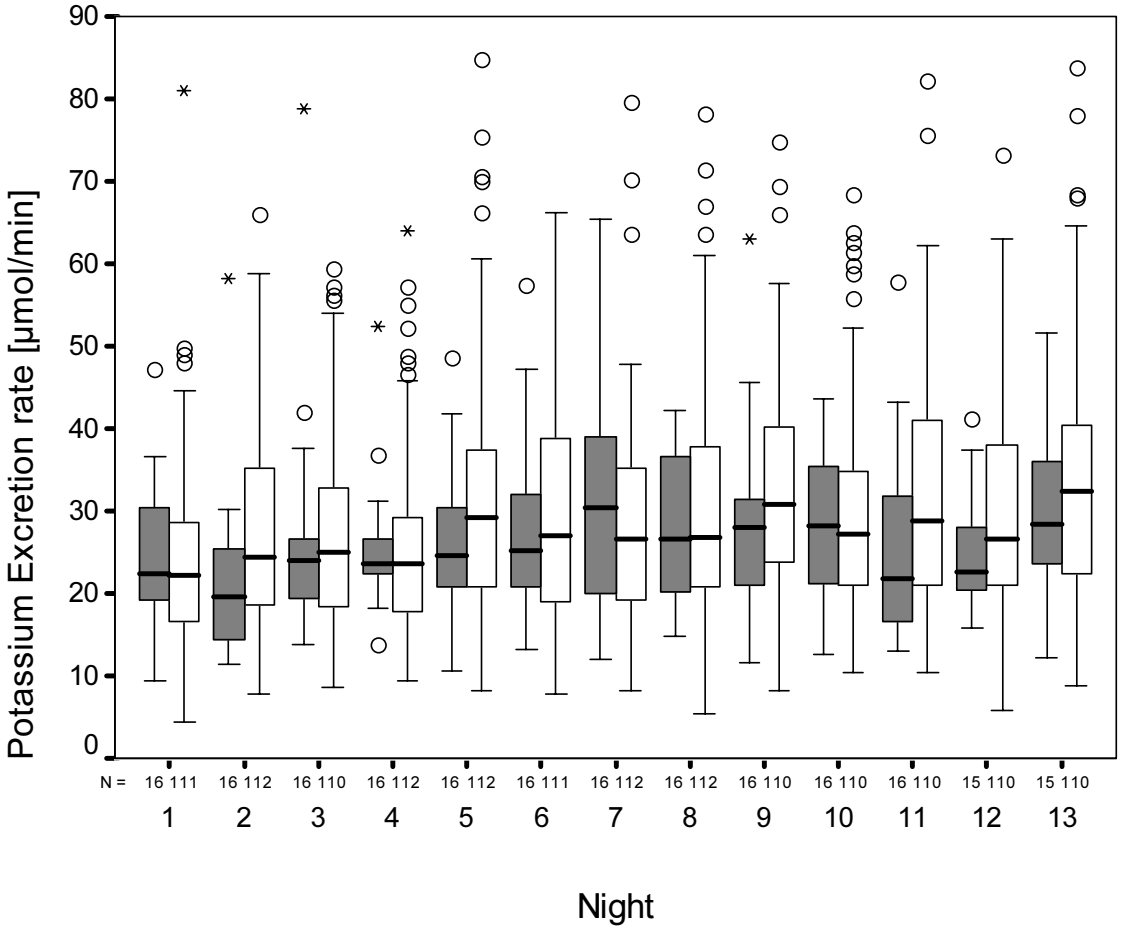

Figure 3.11: Box plot of the potassium excretion rates in all night urine samples in both control group (grey boxes, 16 subjects) and experimental group (light boxes, 112 subjects) during the laboratory studies depending on the consecutive experimental nights. First nights were always Monday/Tuesday nights. N refers to the number of investigated nights.

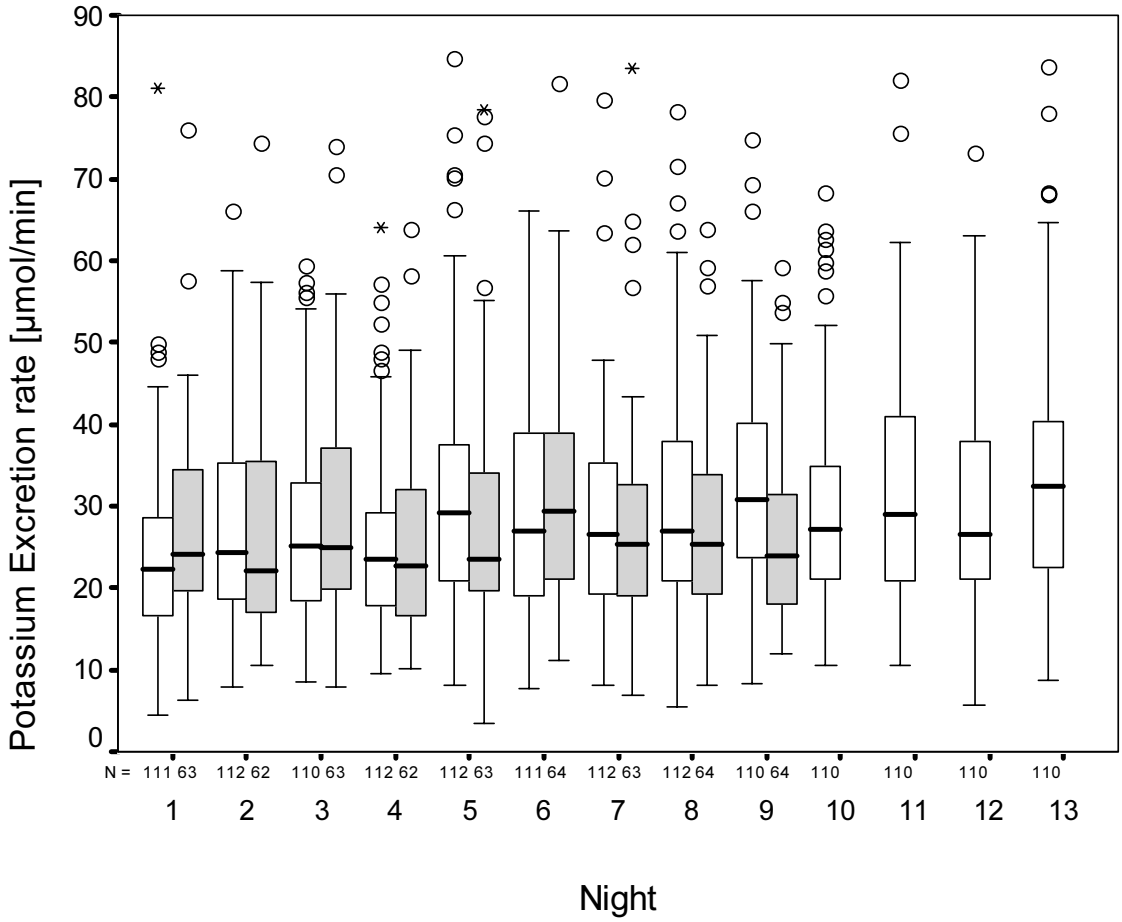

Figure 3.12: Box plot of the potassium excretion rates in all night urine samples during both experimental group in laboratory studies (light boxes, 112 subjects) and the field studies (grey boxes, 64 subjects) depending on the consecutive experimental nights. First nights were always Monday/Tuesday nights. N refers to the number of investigated nights.

Night	Estimated mean ± SE [µmol/min]	Adjusted p-value
Night #1	24.0 ± 1.2	0.306
Night #2	26.6 ± 1.2	Reference
Night #3	26.8 ± 1.2	1.000
Night #4	25.4 ± 1.2	0.961
Night #5	31.4 ± 1.2	**0.003**
Night #6	29.6 ± 1.2	0.188
Night #7	28.4 ± 1.2	0.736
Night #8	30.4 ± 1.2	**0.037**
Night #9	32.2 ± 1.2	**0.001**
Night #10	29.3 ± 1.2	0.291
Night #11	31.4 ± 1.2	**0.003**
Night #12	30.5 ± 1.2	**0.032**
Night #13	34.5 ± 1.2	**0.001**

Table 3.10: Estimated mean potassium excretion rates (± SE) in all night urine samples during laboratory studies, experimental group (n = 112) depending on experimental night and their corresponding adjusted p-values with night #2 serving as reference. Significance $p < 0.05$ in bold.

3.1.3 Magnesium

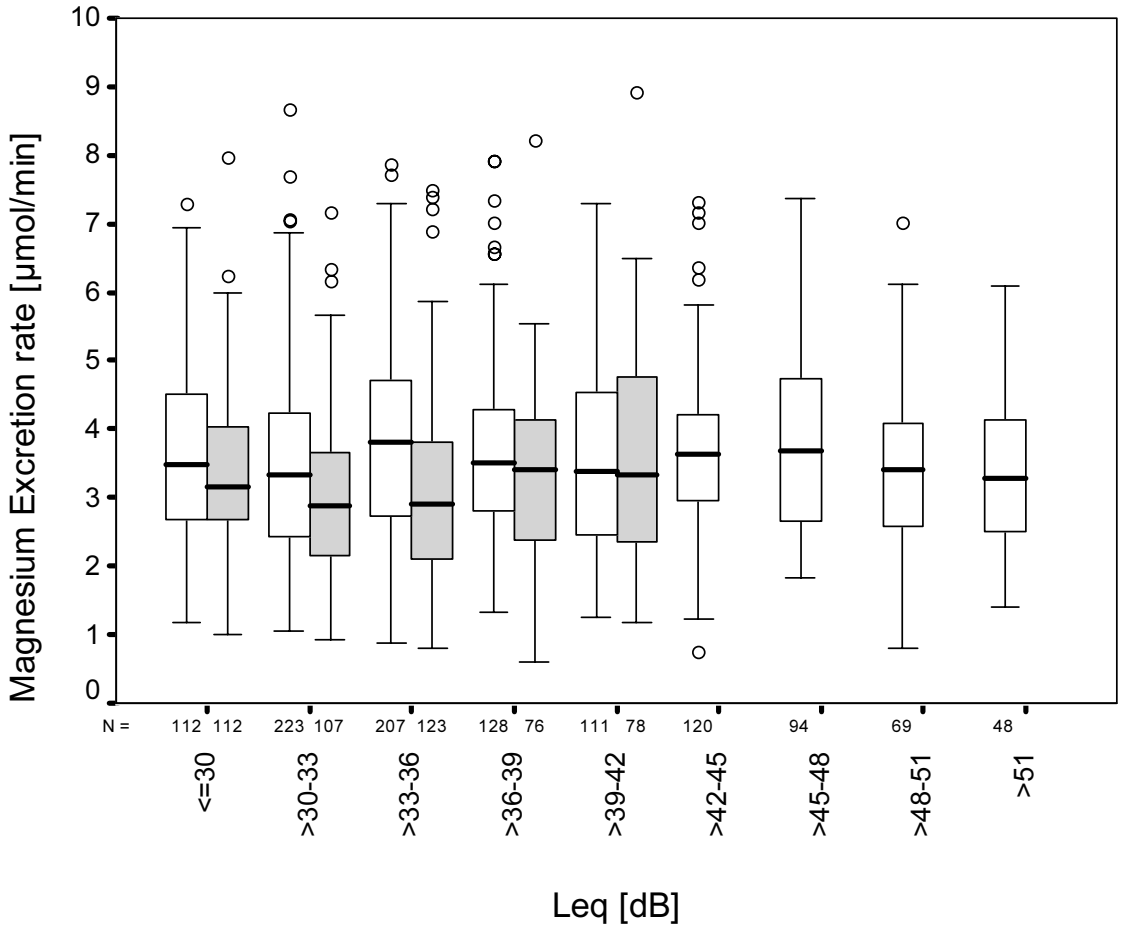

Figure 3.13: Box plot of the magnesium excretion rates in all night urine samples during both laboratory (light boxes) and field (grey boxes) studies depending on L_{eq} classes during the nights. Laboratory studies comprise experimental groups only, with nights 2 – 11, field studies with nights 2 - 9. N refers to the number of investigated nights.

Figure 3.13 shows the box plots of nocturnal urinary magnesium excretion rates depending on the L_{eq} level during the nights. Shown are the results of the experimental groups in the laboratory without nights 1, 12, and 13 having been adaptation and recovery nights without aircraft noise. Baseline night 2 was also noise free (≤ 30 dB). The results are given in light boxes. The results from the field studies are indicated in grey boxes. Here, the first night is omitted as adaptation night.

Normal ranges for magnesium excretion in urine are: 2.1 – 3.5 µmol/min [AAS method, calculated from 24 h excretion, Tietz 1995], respectively 1.7 – 5.9 µmol/min [xylidyl blue method used here, calculated from 24 h excretion, Sitzmann 1986].

The F-test applied to the data of the laboratory experimental group of 112 subjects shows that there is no significant difference in magnesium excretions during baseline nights compared to pooled data of noisy nights ($F = 0.57$ and $p = 0.451$). The mixed model estimates for magnesium excretions during the baseline nights a mean ± SE = 3.58 ± 0.13 µmol/min and for the pooled data of noisy nights a mean ± SE = 3.64 ± 0.10 µmol/min). A univariable regression analysis indicates a statistically non significant and irrelevant decrease of the magnesium excretion rate depending on L_{eq} ($p = 0.558$; -0.003 µmol/min per 1 dB increase L_{eq}).

The F-test applied to the data of the field group of 64 subjects states that there is no significant difference in magnesium excretions during reference nights with an $L_{eq} \leq 30$ dB compared to pooled data of nights with $L_{eq} > 30$ dB ($F = 0.27$ and $p = 0.603$) The mixed model estimates for magnesium excretions during the nights with $L_{eq} \leq 30$ dB a mean ± SE = 3.16 ± 0.16 µmol/min and for the pooled data of nights with $L_{eq} > 30$ dB a mean ± SE = 3.23 ± 0.12 µmol/min. A univariable regression analysis indicates a statistically non significant and irrelevant increase of the magnesium excretion rate depending on L_{eq} ($p = 0.346$; 0.01 µmol/min per 1 dB increase L_{eq}).

There is a significant difference, however, between nocturnal magnesium excretion rates in the laboratory and the field, where the rates are lower ($F = 6.31$ and $p = 0.013$). The estimated mean excretion rates are in the laboratory studies = 3.61 ± 0.09 µmol/min, and in the field studies = 3.22 ± 0.13 µmol/min.

The box plots of Figure 3.14 and Figure 3.15 indicate the nocturnal magnesium excretion rates in the laboratory studies with both increasing SPLs and

increasing numbers of ANEs. The mixed model regression analysis (Table 3.11) indicates a statistically non significant and irrelevant influence of the number of ANEs and the maximum SPL on the magnesium excretion. There is no significant interaction between ANE and SPL (p = 0.943).

Variable	β	p-value
Maximum SPL	-0.00006	0.964
Number of ANE	-0.00016	0.952

Table 3.11: Mixed model regression calculation of nocturnal magnesium excretion rates and its statistical dependency on maximum SPL and number of ANE.

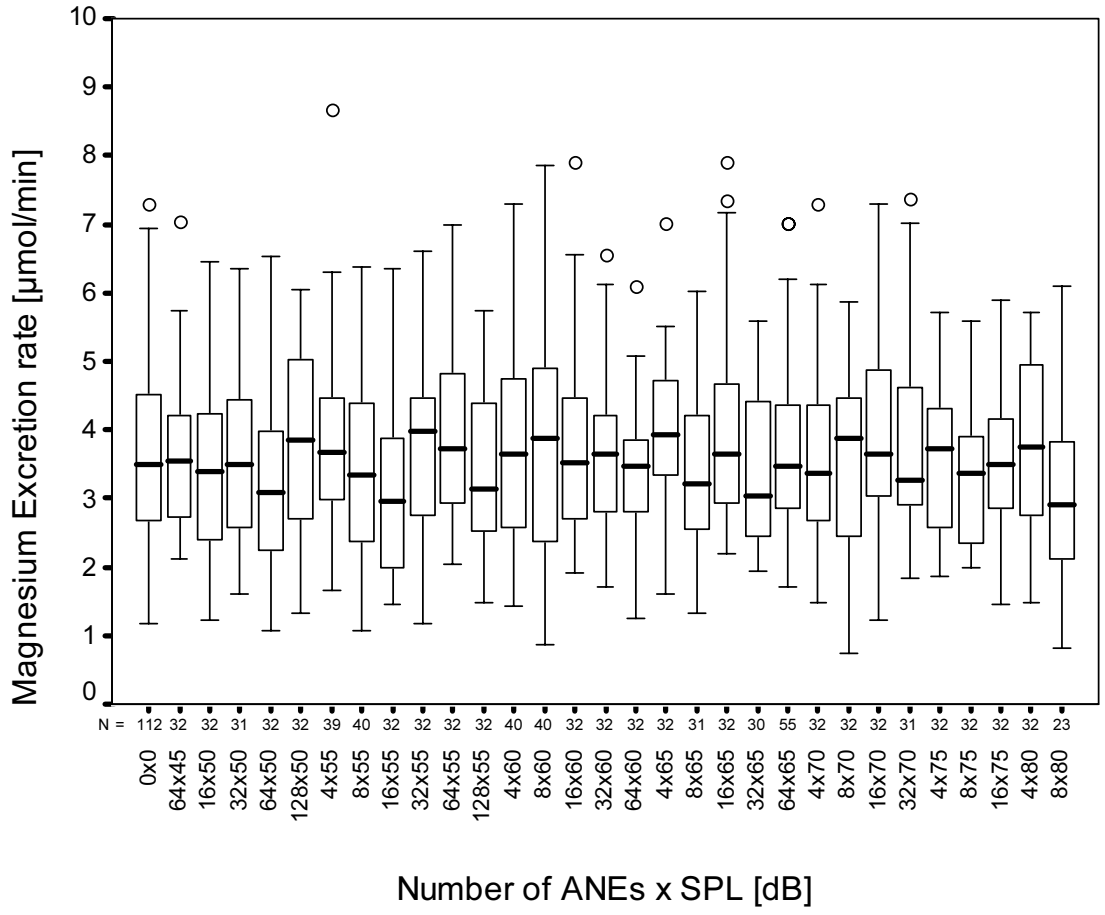

Figure 3.14: Box plot of the magnesium excretion rates in all night urine samples during laboratory studies depending on increasing numbers of aircraft noise events (ANE) and corresponding SPL during the nights. Laboratory studies comprise experimental groups only, with nights 2 – 11. N refers to the number of investigated nights.

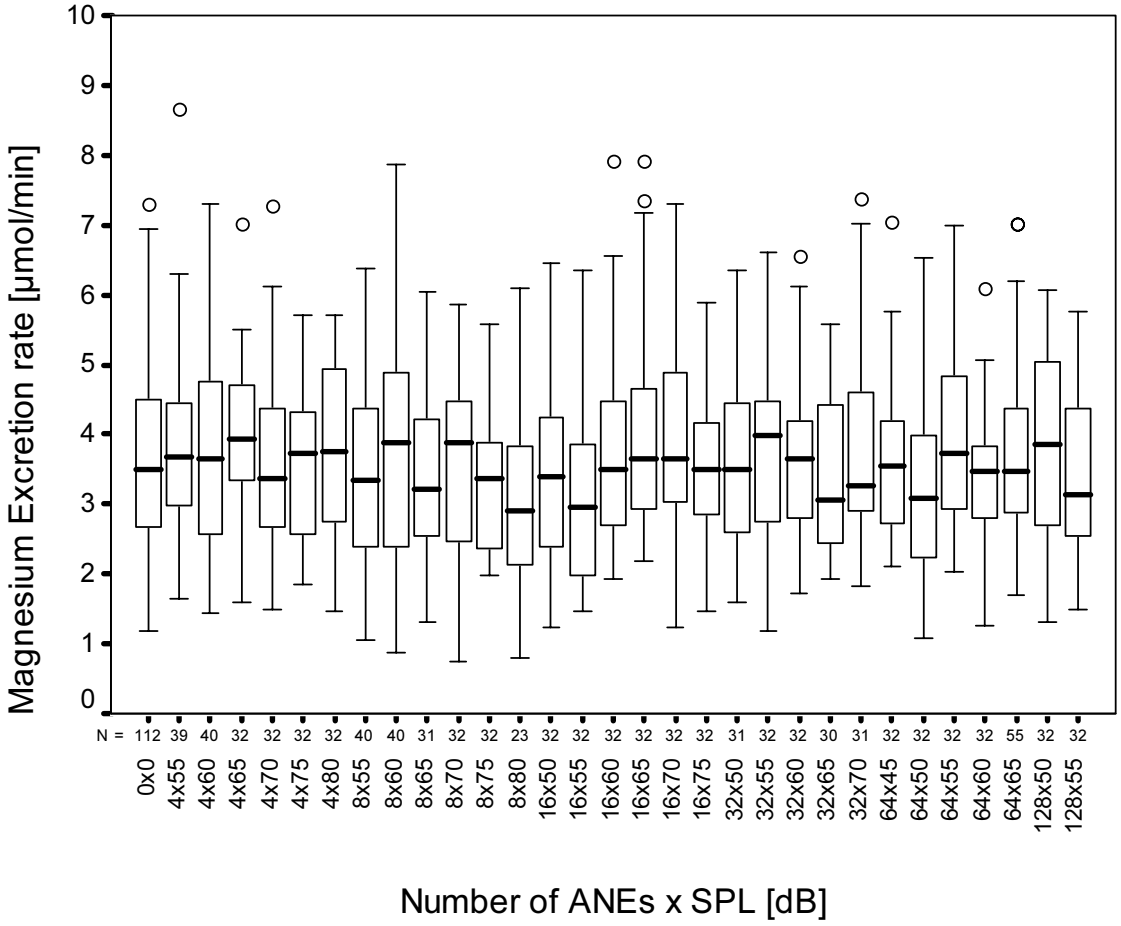

Figure 3.15: Box plot of the magnesium excretion rates in all night urine samples during laboratory studies depending on number of aircraft noise events (ANE) and corresponding increasing SPL during the nights. Laboratory studies comprise experimental groups only with nights 2 – 11. N refers to the number of investigated nights.

Table 3.12 illustrates in detail the statistical evaluation of magnesium excretion rates and their dependency on all interactions of maximum SPL and number of ANE per night in post-hoc tests. According to mixed model calculations magnesium excretion rates are only significantly ($p = 0.004$) higher (mean ± SE = 4.09 ± 0.18 µmol/min) in exposure nights of 16 ANE at 65 dB per night than in baseline nights (3.58 ± 0.13 µmol/min). All other exposure nights do not differ statistically significantly with respect to the magnesium excretion rate.

Maximum SPL LAS,max in dB	Number of Aircraft Noise Events per night					
	4	**8**	**16**	**32**	**64**	**128**
45					3.67±0.18 p=0.612	
50			3.56±0.18 p=0.898	3.66±0.19 p=0.679	3.38±0.18 p=0.255	3.83±0.18 p=0.166
55	3.79±0.17 p=0.214	3.54±0.17 p=0.785	3.29±0.18 p=0.102	3.71±0.19 p=0.479	3.68±0.18 p=0.576	3.40±0.18 p=0.292
60	3.80±0.17 p=0.177	3.69±0.17 p=0.497	3.58±0.18 p=0.999	3.67±0.18 p=0.627	3.60±0.18 p=0.926	
65	3.85±0.18 p=0.134	3.74±0.19 p=0.369	**4.09±0.18** **p=0.004**	3.46±0.19 p=0.499	3.76±0.15 p=0.219	
70	3.53±0.18 p=0.792	3.58±0.18 p=0.994	3.80±0.18 p=0.205	3.73±0.19 p=0.407		
75	3.66±0.18 p=0.649	3.47±0.18 p=0.517	3.62±0.18 p=0.838			
80	3.73±0.18 p=0.403	3.26±0.21 p=0.109				

Table 3.12: Estimated mean magnesium excretion rates (± SE) [µmol/min] in all night urine samples during **experimental** laboratory studies (n = 112) depending on all combinations of maximum SPL and number of ANEs per night applied and their corresponding adjusted p-values with noise free (0x0) night # 2 (estimated mean ± SE = 3.58 ± 0.13 µmol/min) serving as reference. Significance $p < 0.05$ in bold.

Figure 3.16 illustrates the magnesium excretion rates at night during field studies in dependency on the number of traffic noise events per night. None of the exposure categories differs statistically significantly from the overall mean ($F = 1.98$ and $p = 0.097$). There is no dose-response relationship. A mixed model regression analysis (Table 3.13) indicates a statistically non significant and irrelevant influence of the number of traffic noise events per night and L_{eq} on the magnesium excretion. There is no significant interaction between L_{eq} and number of traffic noise events ($p = 0.144$).

Variable	β	p-value
Leq	0.00874	0.536
Number of Traffic Noise Events per Night	0.00225	0.084

Table 3.13: Mixed model regression calculation of nocturnal magnesium excretion rates and its statistical dependency on Leq and number of traffic noise events per night.

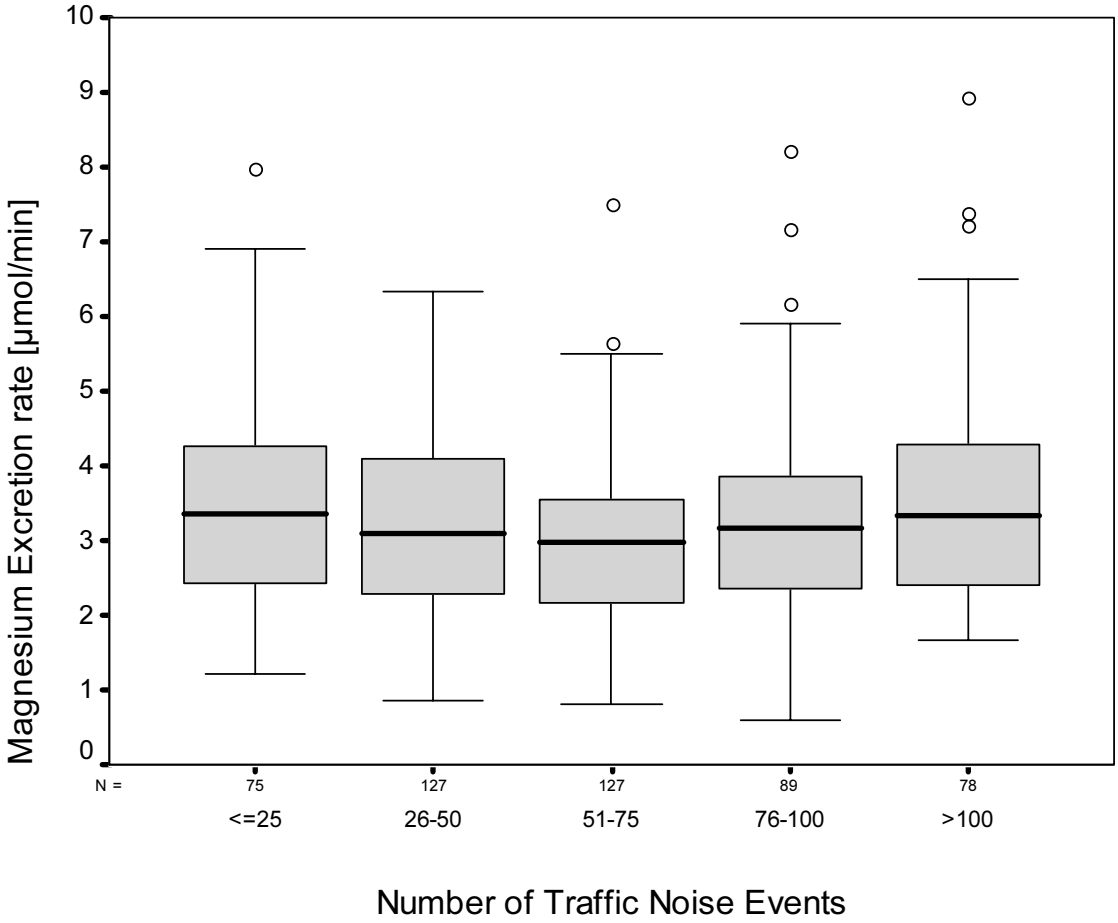

Figure 3.16: Box plot of the magnesium excretion rates in all night urine samples during field studies depending on number of traffic noise events during the nights. Field studies comprise all nights 2 – 9. N refers to the number of investigated nights.

Figure 3.17 and Figure 3.18 show in box plots the magnesium excretion rates in the laboratory studies comparing experimental and control groups, as well as in the field studies in dependency on the experimental night.

In the control group, none of the exposure nights 1 – 13 differs statistically significantly from the overall mean (F-test: $F = 1.26$ and $p = 0.246$).

In the laboratory experimental group, the result of the F-test indicates that at least one of the experiment nights differs statistically significantly from the overall mean ($F = 3.72$ and $p < 0.001$). Post-hoc tests shown in Table 3.14 reveal that the magnesium excretion rate only during adaptation night #1 is significantly lower (3.26 ± 0.12 µmol/min) than that one during reference night #2 (3.58 ± 0.12 µmol/min). None of the other nights, including recovery and last night, differs significantly from the reference night.

In the field group, the result of the F-test indicates that at least one of the nights differs statistically significantly from the overall mean (F-test: $F = 2.24$ and $p = 0.023$). Post-hoc tests shown in Table 3.15, however, reveal that the magnesium excretion rate during reference night #2 does not differ significantly from all other nights.

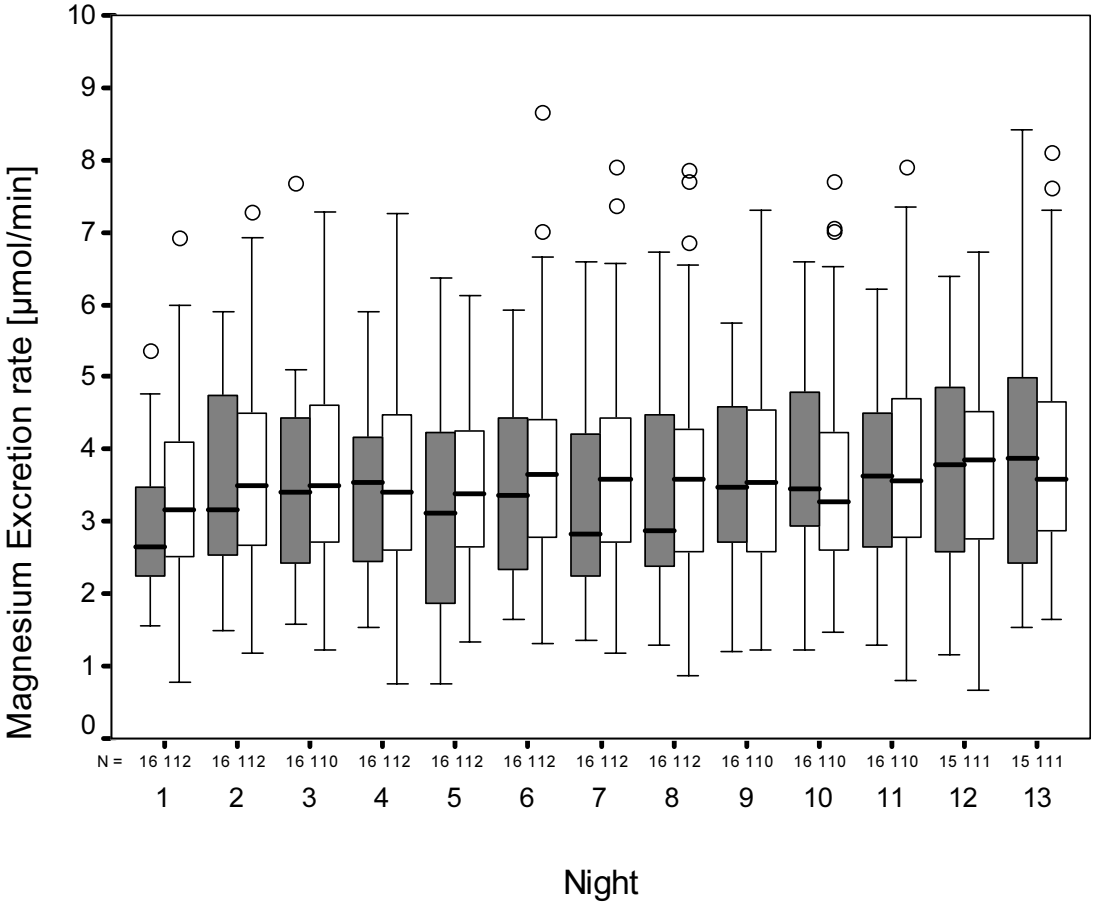

Figure 3.17: Box plot of the magnesium excretion rates in all night urine samples in both control group (grey boxes, 16 subjects) and experimental group (light boxes, 112 subjects) during the laboratory studies depending on the consecutive experimental nights. First nights were always Monday/Tuesday nights. N refers to the number of investigated nights.

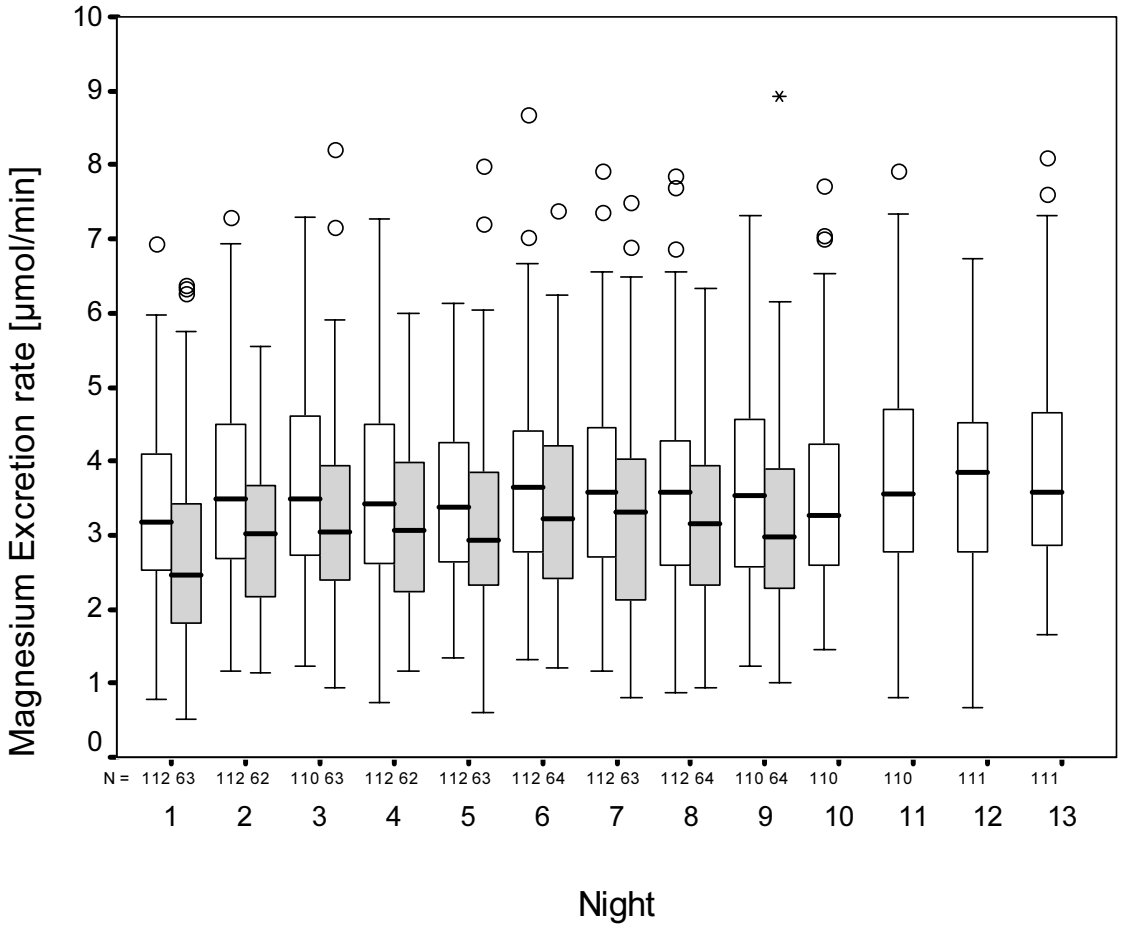

Figure 3.18: Box plot of the magnesium excretion rates in all night urine samples during both experimental group in laboratory studies (light boxes, 112 subjects) and in the field studies (grey boxes, 64 subjects) depending on the consecutive experimental nights. First nights were always Monday/Tuesday nights. N refers to the number of investigated nights.

Night	Estimated mean ± SE [µmol/min]	Adjusted p-value
Night #1	3.26 ± 0.12	**0.043**
Night #2	3.58 ± 0.12	Reference
Night #3	3.76 ± 0.13	0.588
Night #4	3.59 ± 0.12	1.000
Night #5	3.52 ± 0.12	1.000
Night #6	3.71 ± 0.12	0.902
Night #7	3.67 ± 0.12	0.993
Night #8	3.58 ± 0.12	1.000
Night #9	3.69 ± 0.13	0.962
Night #10	3.51 ± 0.13	1.000
Night #11	3.78 ± 0.13	0.447
Night #12	3.74 ± 0.12	0.703
Night #13	3.87 ± 0.12	0.094

Table 3.14: Estimated mean magnesium excretion rates (± SE) in all night urine samples during laborytory studies, experimental group (n = 112) depending on experimental night and their corresponding adjusted p-values with night #2 serving as reference. Significance ($p < 0.05$) is highlighted in bold.

Night	Estimated mean ± SE [µmol/min]	Adjusted p-value
Night #1	2.80 ± 0.16	0.683
Night #2	3.02 ± 0.17	Reference
Night #3	3.35 ± 0.16	0.216
Night #4	3.20 ± 0.17	0.837
Night #5	3.16 ± 0.16	0.943
Night #6	3.33 ± 0.16	0.275
Night #7	3.28 ± 0.16	0.465
Night #8	3.26 ± 0.16	0.550
Night #9	3.13 ± 0.16	0.985

Table 3.15: Estimated mean magnesium excretion rates (± SE) in all night urine samples during field studies (n = 64) depending on experimental night and their corresponding adjusted p-values with night #2 serving as reference. Significance $p < 0.05$ in bold.

3.1.4 Calcium

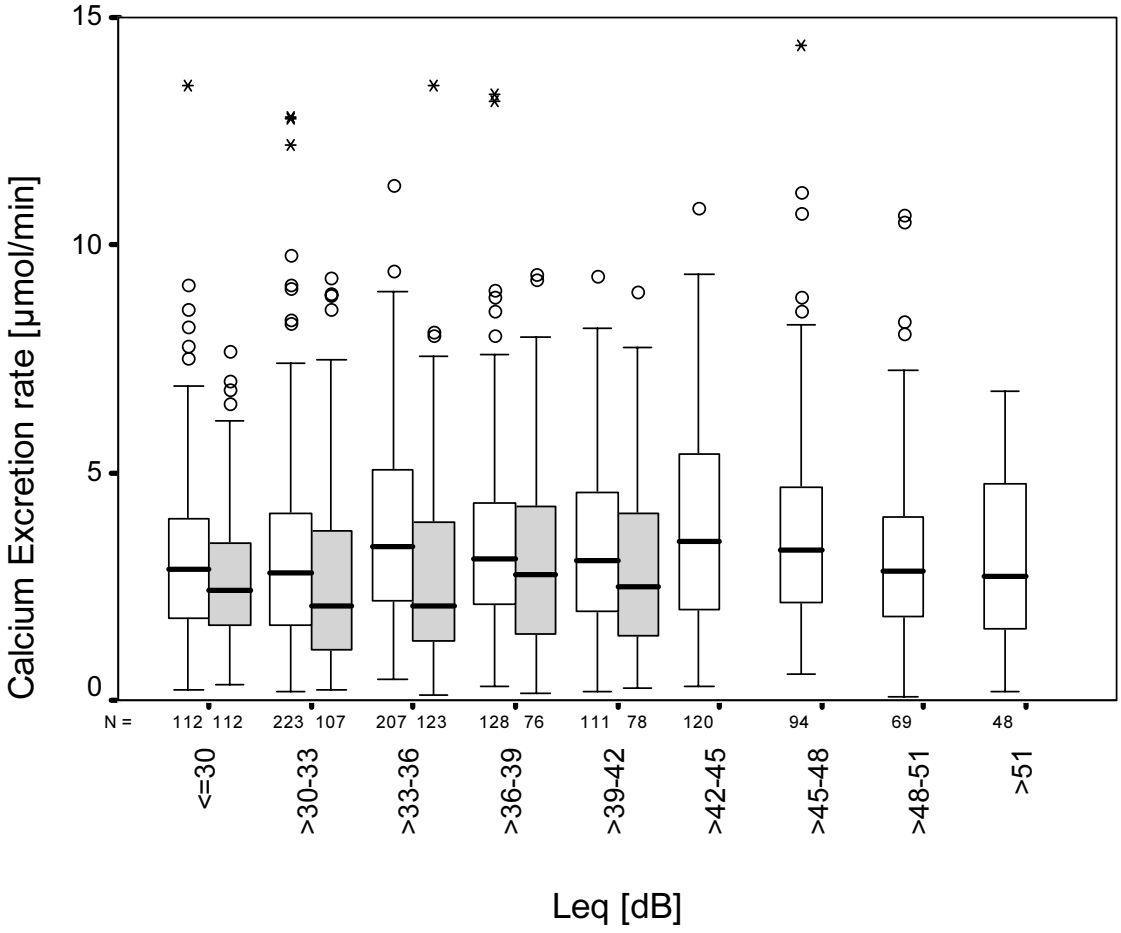

Figure 3.19: Box plot of the calcium excretion rates in all night urine samples during both laboratory (light boxes) and field (grey boxes) studies depending on L_{eq} classes during the nights. Laboratory studies comprise experimental groups only, with nights 2 – 11, field studies with nights 2 - 9. N refers to the number of investigated nights.

Figure 3.19 shows the box plot of nocturnal urinary calcium excretion rates depending on the L_{eq} level during the nights. Shown are the results of the experimental groups in the laboratory without nights 1, 12, and 13 having been adaptation and recovery nights without aircraft noise. Baseline night 2 was also noise free (≦ 30 dB). The results are given in light boxes. Results from the field studies are indicated in grey boxes. First night is omitted as being considered an adaptation night.

Normal range for calcium in urine (AAS and spectrophotomethric methods) is 1.7 – 5.2 µmol/min [calculated from 24 h excretion, Tietz 1995].

The F-test applied to the data of the laboratory experimental group of 112 subjects shows that at least one of the Leq classes differs statistically significantly from the overall mean ($F = 6.77$ and $p = 0.009$). Post-hoc tests shown in Table 3.16 reveal that the calcium excretion rates in Leq classes 36 ≤ 39 dB (3.62 ± 0.20 µmol/min) and 42 ≤ 45 dB (3.63 ± 0.21 µmol/min) are significantly higher than in the baseline group Leq ≤ 30 dB. The mixed model estimates for calcium excretions during the baseline nights a mean ± SE = 3.19 ± 0.20 µmol/min and for the pooled data of noisy nights a mean ± SE = 3.49 ± 0.17 µmol/min. A univariable regression analysis indicates a statistically non significant and irrelevant increase of the calcium excretion rate depending on Leq ($p = 0.968$; 0.0002 µmol/min per 1 dB increase Leq).

The F-test applied to the data of the field group of 64 subjects states that there is no relevant or significant difference in calcium excretions during reference nights with an Leq ≤ 30 dB compared to pooled data of nights with Leq > 30 dB ($F = 0.46$ and $p = 0.500$). The mixed model estimates for calcium excretions during nights with an Leq ≤ 30 dB a mean ± SE = 2.71 ± 0.24 µmol/min and for the pooled data of nights with Leq > 30 dB a mean ± SE = 2.83 ± 0.21 µmol/min. A univariable regression analysis indicates a statistically non significant and irrelevant increase of the calcium excretion rate depending on Leq ($p = 0.407$; 0.02 µmol/min per 1 dB increase Leq).

There is a significant difference, however, between nocturnal calcium excretion rates in the laboratory and the field, where the rates are lower ($F = 4.97$ and $p = 0.027$). The estimated mean excretion rates are in the laboratory studies = 3.38 ± 0.15 µmol/min, and in the field studies = 2.79 ± 0.22 µmol/min.

Leq classes	Estimated mean ± SE [µmol/min]	Adjusted p-value
≤ 30 dB	3.19 ± 0.20	Reference
>30-33 dB	3.37 ± 0.19	0.753
>33-36 dB	3.52 ± 0.19	0.128
>36-39 dB	3.62 ± 0.20	**0.033**
>39-42 dB	3.47 ± 0.20	0.418
>42-45 dB	3.63 ± 0.20	**0.031**
>45-48 dB	3.63 ± 0.21	0.051
>48-51 dB	3.37 ± 0.22	0.933
> 51 dB	3.27 ± 0.27	1.000

Table 3.16: Estimated mean calcium excretion rates (± SE) in all night urine samples during laboratory studies depending on Leq classes during these nights, and their corresponding adjusted p-values with Leq class ≤ 30 dB serving as reference. Significance $p < 0.05$ in bold.

The box plots of Figure 3.20 and Figure 3.21 indicate the nocturnal calcium excretion rates in the laboratory studies with both increasing SPLs and increasing numbers of ANEs. The mixed model regression analysis (Table 3.17) indicates a statistically non significant and irrelevant influence of the number of ANEs and the maximum SPL on the calcium excretion. There is no significant interaction between ANE and SPL ($p = 0.495$).

Variable	β	p-value
Maximum SPL	0.00417	0.375
Number of ANE	0.00063	0.629

Table 3.17: Mixed model regression calculation of nocturnal calcium excretion rates and its statistical dependency on maximum SPL and number of ANE.

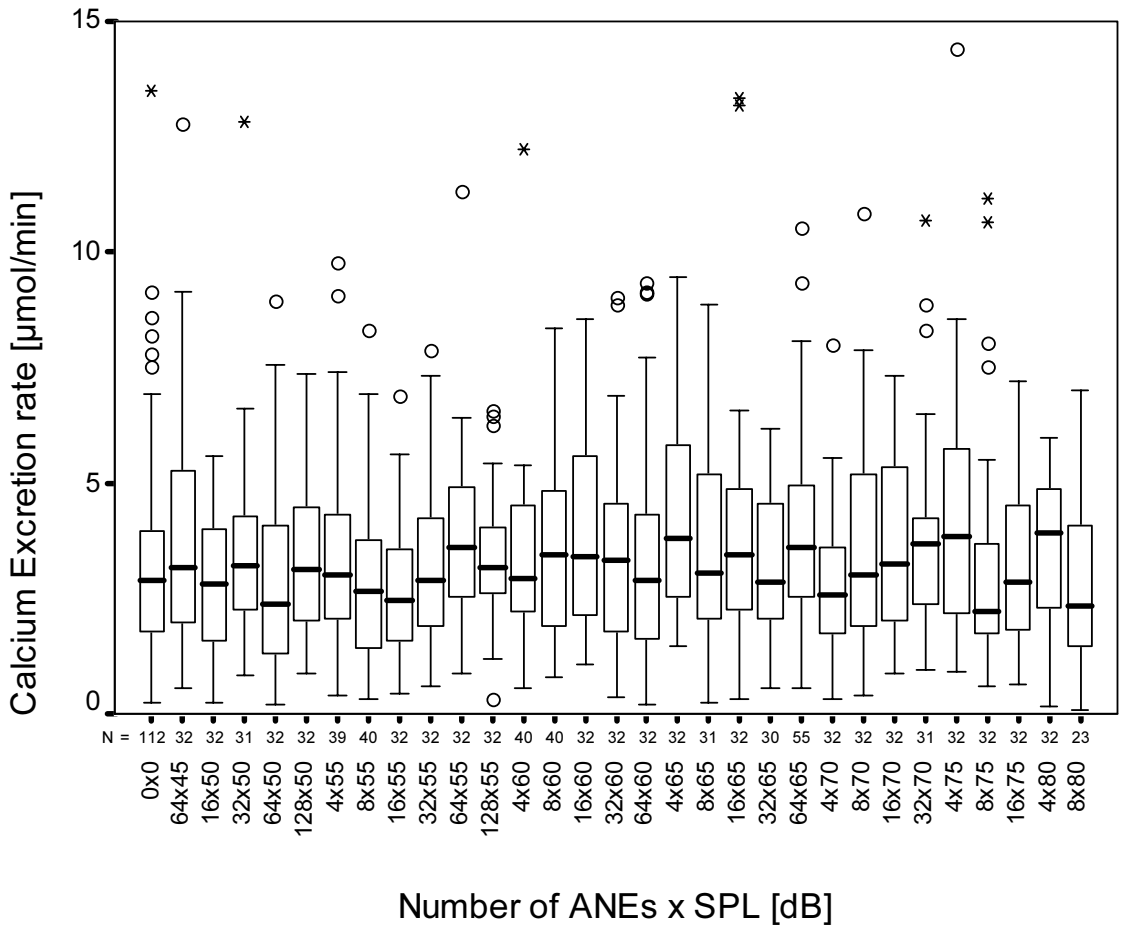

Figure 3.20: Box plot of the calcium excretion rates in all night urine samples during laboratory studies depending on increasing numbers of aircraft noise events (ANE) and corresponding SPL during the nights. Laboratory studies comprise experimental groups only, with nights 2 – 11. N refers to the number of investigated nights.

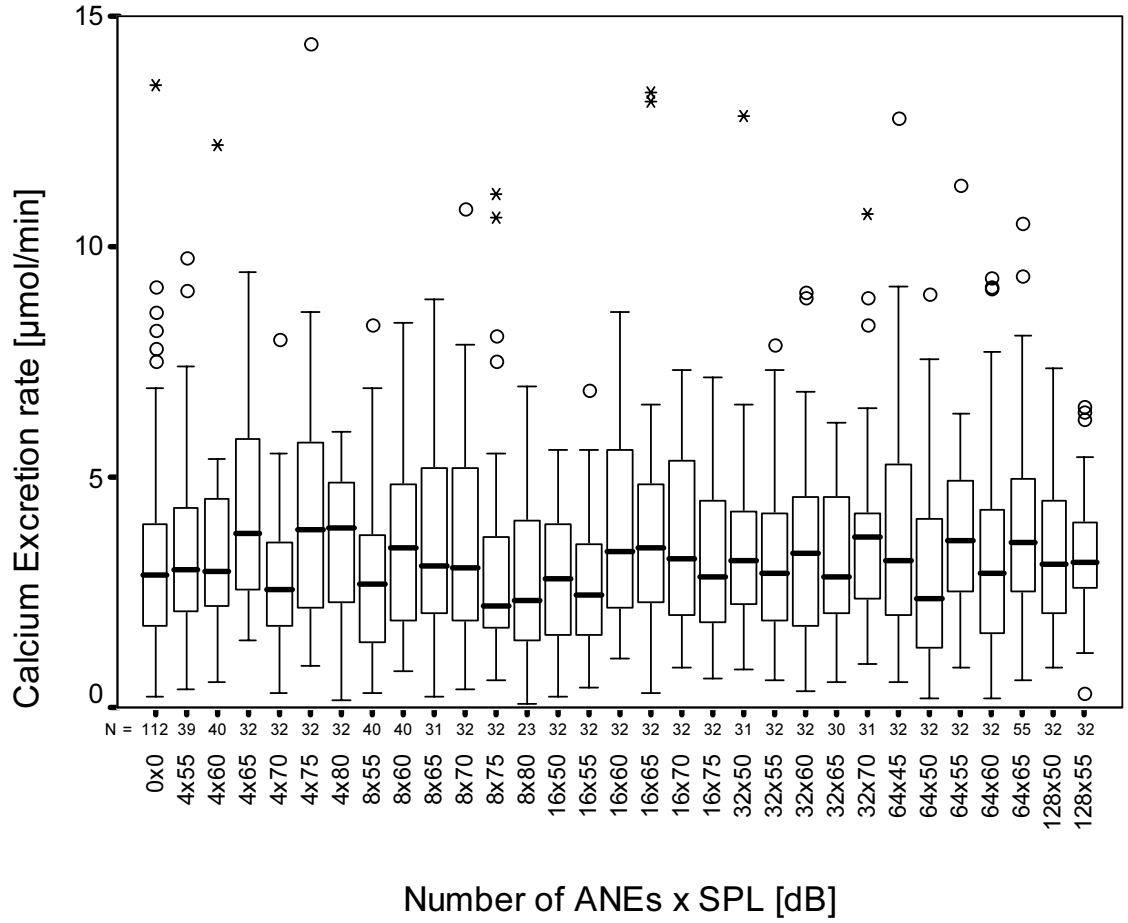

Figure 3.21: Box plot of the calcium excretion rates in all night urine samples during laboratory studies depending on number of aircraft noise events (ANE) and corresponding increasing SPL during the nights. Laboratory studies comprise experimental groups only with nights 2 – 11. N refers to the number of investigated nights.

Table 3.18 illustrates in detail the statistical evaluation of calcium excretion rates and their dependency on all combinations of maximum SPL and number of ANE per night. According to mixed model calculations, calcium excretion rates are significantly higher than the baseline rate (3.19 ± 0.20 µmol/min) in 10 out of 30 combinations.

Maximum SPL LAS,max in dB	Number of Aircraft Noise Events per night					
	4	**8**	**16**	**32**	**64**	**128**
45					**3.68±0.27 p=0.037**	
50			3.14±0.27 p=0.818	3.57±0.27 p=0.114	2.93±0.27 p=0.262	**3.73±0.27 p=0.022**
55	**3.76±0.26 p=0.011**	3.33±0.26 p=0.552	3.05±0.27 p=0.539	3.43±0.27 p=0.317	3.43±0.27 p=0.313	3.31±0.27 p=0.608
60	3.45±0.26 p=0.248	3.52±0.26 p=0.142	3.21±0.27 p=0.952	**3.76±0.27 p=0.017**	3.50±0.27 p=0.194	
65	**3.72±0.27 p=0.025**	**3.81±0.27 p=0.009**	**4.19±0.27 p=0.001**	3.46±0.28 p=0.275	**3.55±0.23 p=0.062**	
70	3.21±0.27 p=0.952	**3.59±0.27 p=0.095**	3.50±0.27 p=0.188	3.50±0.27 p=0.194		
75	**4.00±0.27 p=0.001**	3.42±0.27 p=0.335	3.28±0.27 p=0.712			
80	3.52±0.27 p=0.165	3.01±0.30 p=0.492				

Table 3.18: Estimated mean calcium excretion rates (± SE) [µmol/min] in all night urine samples during **experimental** laboratory studies (n = 112) depending on all combinations of maximum SPL and number of ANEs per night applied and their corresponding adjusted p-values with noise free (0x0) night # 2 (estimated mean ± SE = 3.19 ± 0.20 µmol/min) serving as reference. Significance $p < 0.05$ in bold.

Figure 3.22 illustrates the calcium excretion rates at night during field studies in dependency on the number of traffic noise events per night. None of the exposure categories differs statistically significantly from the overall mean ($F = 1.30$ and $p = 0.271$). There is no dose-response relationship. A mixed model regression analysis (Table 3.19) indicates a statistically non significant and irrelevant influence of the number of traffic noise events per night and L_{eq} on the calcium excretion. There is no significant interaction between L_{eq} and number of traffic noise events ($p = 0.161$).

Variable	β	p-value
Leq	0.01151	0.550
Number of Traffic Noise Events per Night	0.00246	0.175

Table 3.19: Mixed model regression calculation of nocturnal calcium excretion rates and its statistical dependency on Leq and number of traffic noise events per night.

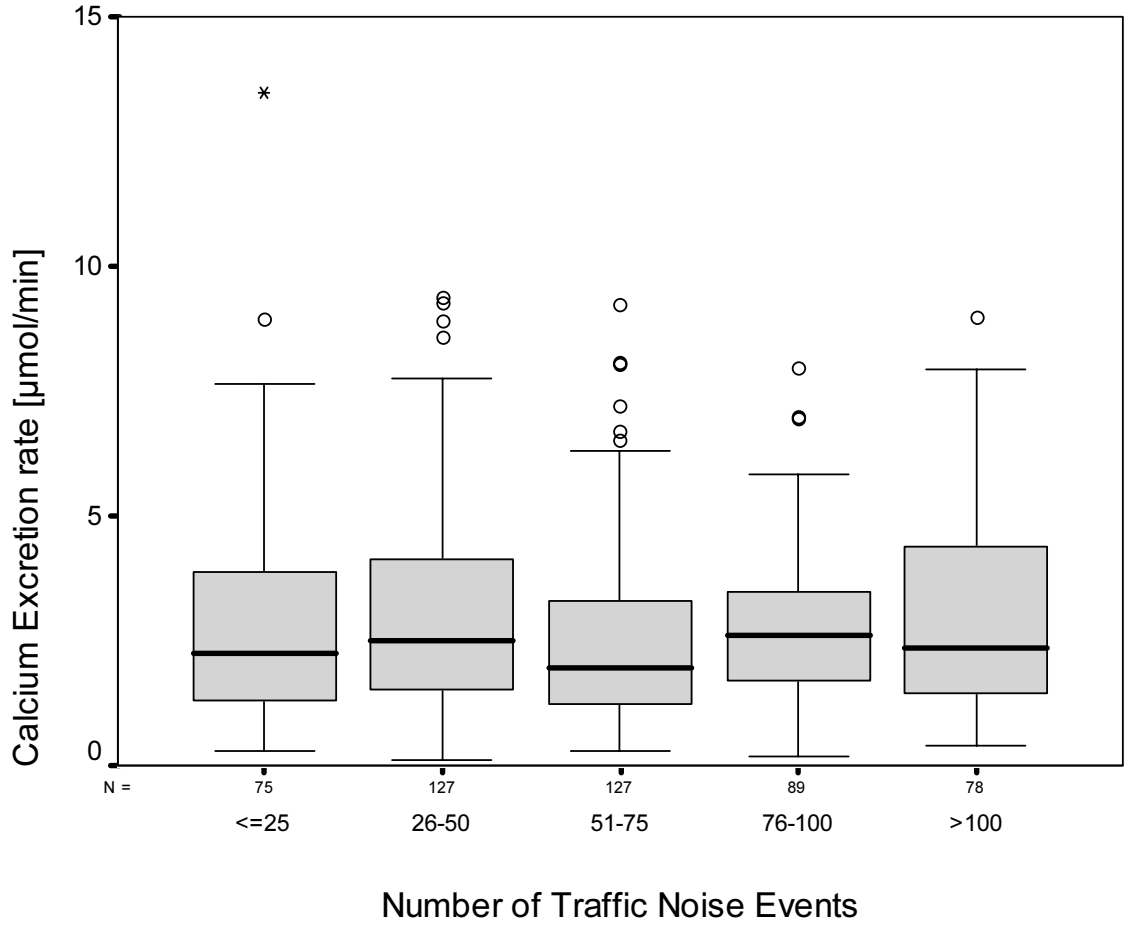

Figure 3.22: Box plot of the calcium excretion rates in all night urine samples during field studies depending on number of traffic noise events during the nights. Field studies comprise all nights 2 – 9. N refers to the number of investigated nights.

Figure 3.23 and Figure 3.24 show in box plots the calcium excretion rates in the laboratory studies comparing experimental and control groups, as well as in the field studies in dependency on the experimental night.

In the control group, none of the exposure nights 1 – 13 differs statistically significantly from the overall mean (F-test: $F = 0.93$ and $p = 0.515$).

In the laboratory experimental group, the result of the F-test indicates that at least one of the nights differs statistically significantly from the overall mean ($F = 6.46$ and $p < 0.001$). Post-hoc tests shown in Table 3.20 reveal that the calcium excretion rates during nights #7, #11 , and #13 are significantly higher than that one during reference night #2 (3.19 ± 0.2 µmol/min). None of the other nights, including adaptation and recovery night, differs significantly from the reference night.

In the field group, the result of the F-test indicates that at least one of the experiment nights differs statistically significantly from the overall mean ($F = 2.24$ and $p = 0.024$). Post-hoc tests shown in Table 3.21 reveal statistically no different calcium excretion rates from the reference night #2.

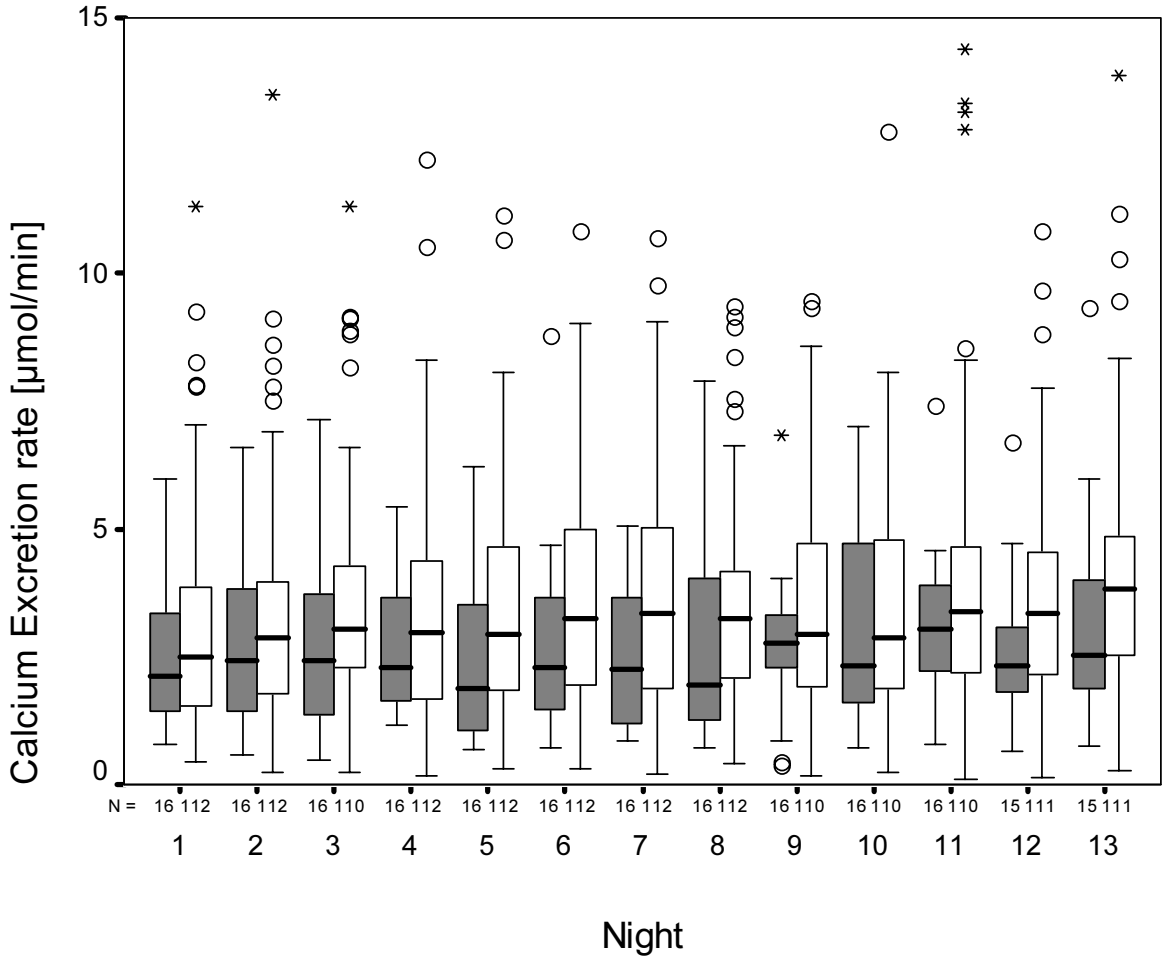

Figure 3.23: Box plot of the calcium excretion rates in all night urine samples during both control group (grey boxes, 16 subjects) and experimental group (light boxes, 112 subjects) in the laboratory studies depending on the consecutive experimental nights. First nights were always Monday/Tuesday nights. N refers to the number of investigated nights.

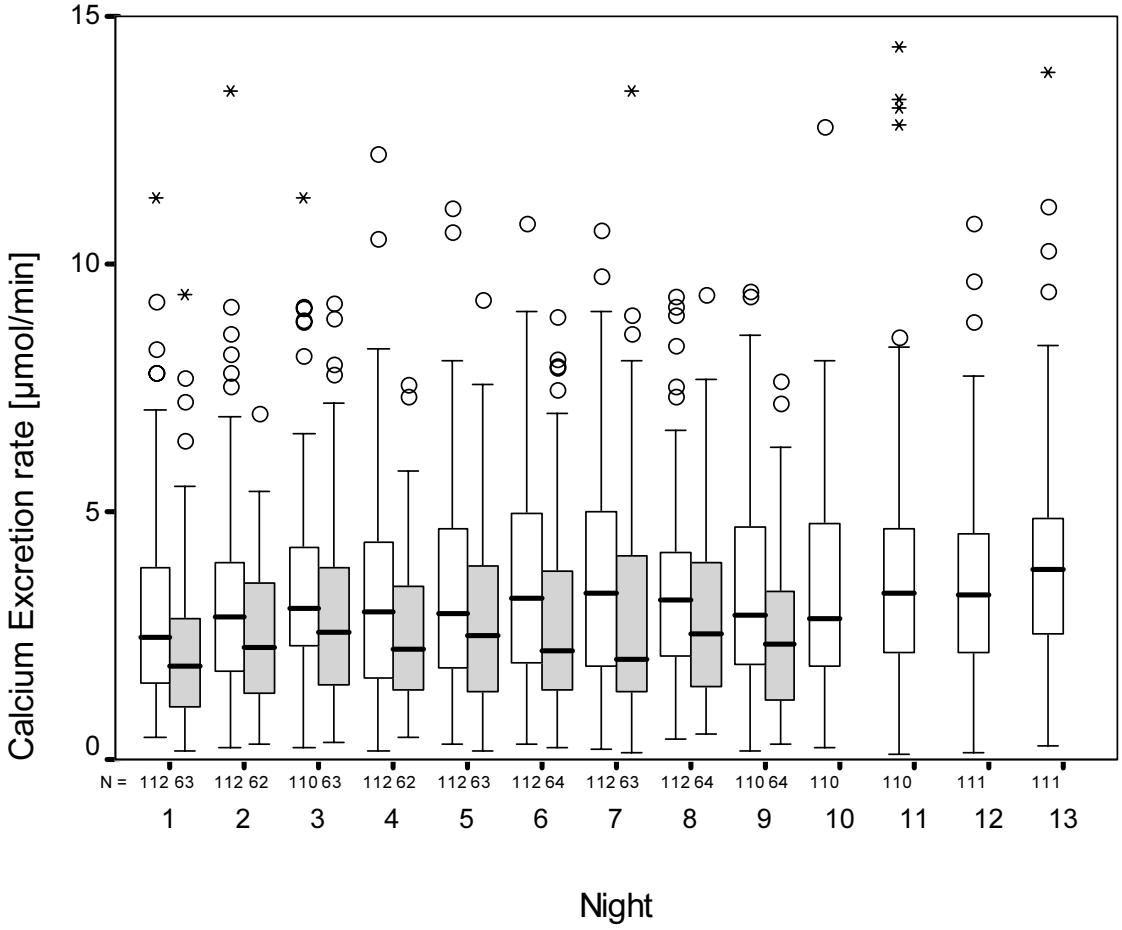

Figure 3.24: Box plot of the calcium excretion rates in all night urine samples during both experimental group in laboratory studies (light boxes, 112 subjects) and in the field studies (grey boxes, 64 subjects) depending on the consecutive experimental nights. First nights were always Monday/Tuesday nights. N refers to the number of investigated nights.

Night	Estimated mean ± SE [µmol/min]	Adjusted p-value
Night #1	2.97 ± 0.20	0.434
Night #2	3.19 ± 0.20	Reference
Night #3	3.46 ± 0.20	0.458
Night #4	3.33 ± 0.20	0.981
Night #5	3.36 ± 0.20	0.906
Night #6	3.60 ± 0.20	0.055
Night #7	3.61 ± 0.20	**0.046**
Night #8	3.46 ± 0.20	0.428
Night #9	3.46 ± 0.20	0.434
Night #10	3.30 ± 0.20	0.998
Night #11	3.84 ± 0.20	**0.001**
Night #12	3.57 ± 0.20	0.094
Night #13	3.97 ± 0.20	**0.001**

Table 3.20: Estimated mean calcium excretion rates (± SE) in all night urine samples during laborytory studies, experimental group (n = 112) depending on experimental night and their corresponding adjusted p-values with night #2 serving as reference. Significance $p < 0.05$ in bold

Night	Estimated mean ± SE [µmol/min]	Adjusted p-value
Night #1	2.40 ± 0.25	0.999
Night #2	2.49 ± 0.25	Reference
Night #3	3.04 ± 0.25	0.063
Night #4	2.71 ± 0.25	0.880
Night #5	2.75 ± 0.25	0.756
Night #6	2.91 ± 0.25	0.239
Night #7	3.01 ± 0.25	0.089
Night #8	2.90 ± 0.25	0.277
Night #9	2.63 ± 0.25	0.987

Table 3.21: Estimated mean calcium excretion rates (± SE) in all night urine samples during field studies (n = 64) depending on experimental night and their corresponding adjusted p-values with night #2 serving as reference. Significance $p < 0.05$ in bold

3.2 Catecholamines

3.2.1 Adrenaline

Table 3.22 illustrates all combinations of number of ANEs per night during the laboratory experimental studies and their corresponding maximum SPLs, and appropriate percentage of detectable nocturnal adrenaline excretions. Nights 1, 12, and 13 are excluded, since these nights were noise free adaptation and recovery nights. Thus, in total 1120 nights (nights 2 - 11) are taken into account, of which 112 were noise free.

		Number of Aircraft Noise Events per night					
		4	**8**	**16**	**32**	**64**	**128**
Maximum SPL LAS,max in dB	**45**					**13 of 31 42%**	
	50			11 of 32 34%	6 of 32 19%	5 of 32 16%	8 of 32 25%
	55	9 of 40 23%	14 of 40 35%	10 of 31 32%	8 of 30 27%	6 of 32 19%	**14 of 31 45%**
	60	7 of 40 18%	8 of 40 20%	6 of 32 19%	**12 of 32 38%**	9 of 32 28%	
	65	4 of 32 13%	11 of 32 34%	7 of 32 22%	8 of 32 25%	16 of 56 29%	
	70	8 of 32 25%	**12 of 32 38%**	9 of 32 28%	9 of 32 28%		
	75	7 of 31 23%	8 of 31 26%	10 of 32 31%			
	80	10 of 31 32%	**10 of 23 43%**				

Table 3.22: Detection of nocturnal urinary adrenaline during laboratory experimental studies (nights 2 – 11, n =112) depending on number of ANEs per night and their maximum SPLs. In combinations printed in bold percentage of detection was higher than in noise free nights (0 x 0) when 40 samples out of 112 nights (= 36%) showed detectable adrenaline concentrations.

Within the laboratory experimental groups adrenaline is detected successfully in 40 nocturnal urine samples out of 112 (= 36%) taken during the noise free baseline night (night #2) with maximum flux rates of up to 2.62 ng/min. 70 out of these 112 urine samples show non detectable levels of adrenaline, and 2 are missing values. In comparison 99 out of the 112 (= 88%) samples collected between 7:00 p.m. and 11:00 p.m. during the same **evenings** test positive for adrenaline, 88 of them > 2 ng/min, and with a maximum value of 19.7 ng/min.

During the noisy nights, 723 urine samples out of 1008 (= 72%) test negative for adrenaline, 74 samples (= 7%) < 1 ng/min, 144 samples (= 14%) 1 ≤ 2 ng/min, 38 samples (= 4%) 2 ≤ 3 ng/min, and 20 samples (= 2%) 3 ≤ 6.5 ng/min. 9 nights (= 1%) are without result, as samples were lost. Table 3.22 illustrates that only in the following combinations of number of ANEs per night * maximum SPL, 64x45, 128x55, 32x60, 8x70, and 8x80, the percentage of detection of adrenaline is higher than in the noise free baseline nights. In contrast and for comparison, samples taken in the same **evenings** show detectable adrenaline levels in 851 out of 1008 (= 84%) samples. 65% of these samples have rates of > 1 ng/min and < 6.5 ng/min.

Within the control groups (n = 16), 25 urine samples out of 160 nights (= 15%) show detectable adrenaline concentrations with rates ranging up to a maximum flux of 2.31 ng/min. 134 urine samples (= 84%) remain below detection level, the value of one night's sample is missing. In contrast, urine samples collected during the **evenings** in control groups between 7:00 pm and 11:00 pm show well detectable adrenaline concentrations. 141 out of 160 (= 88%) urines test positive, and only 19 are too low in adrenaline concentration. The maximum flux rate during the evening in controls is > 12 ng/min and 109 urine samples show rates > 2 ng/min.

Table 3.23 shows the detection of nocturnal adrenaline excretions of the laboratory experimental groups (n = 112, nights 2 – 11) within the different Leq classes. In Leq classes, where aircraft noise was applied, only between 18% and 31% of the urine samples contain sufficient adrenaline to be detected. The vast majority is too low in adrenaline concentration. Maximum flux rates > 3 ng/min occur as singular values regardless of noise events. Samples from nights of Leq > 54 dB, the highest noise class applied, show no detectable adrenaline excretions.

Statistical evaluation fails due to too many missing values.

Leq class[dB]	**Adrenaline detection**	**% of nights**	**Maximum Value [ng/min]**
≤ 30	40 out of 112 nights	36	2.82
> 30 - 33	51 out of 223 nights	23	4.05
> 33 - 36	60 out of 191 nights	31	5.03
> 36 - 39	30 out of 144 nights	21	3.73
> 39 - 42	23 out of 111 nights	21	5.16
> 42 - 45	22 out of 119 nights	18	3.18
> 45 - 48	23 out of 94 nights	24	3.29
> 48 - 51	16 out of 70 nights	23	2.42
> 51 - 54	8 out of 32 nights	25	2.89
> 54	0 out of 16 nights	0	Below detection

Table 3.23: Detection of nocturnal urinary adrenaline during experimental laboratory studies (nights 2 – 11, n = 112) within different Leq classes. Control nights without aircraft noise are in Leq class ≤ 30 dB.

Leq class [dB]	Adrenaline detection	% of nights	Maximum value [ng/min]
≤ 30	**56 out of 121 nights**	**46**	**3.64**
> 30 - 33	50 out of 118 nights	42	4.24
> 33 - 36	51 out of 109 nights	47	3.24
> 36 - 39	28 out of 65 nights	43	3.08
> 39 - 42	28 out of 53 nights	53	2.77
> 42	5 out of 19 nights	26	1.29

Table 3.24: Detection of nocturnal urinary adrenaline during field studies (nights 2 – 9, n = 64) with different Leq classes at the sleeper's ears. Leq ≤ 30 dB corresponds to nights without aircraft noise in the laboratory in bold.

Table 3.24 shows the detection of nocturnal adrenaline excretions during the field studies (n = 64, nights 2 – 9) within the different Leq classes measured indoors, at the sleeper's ears. First nights and nights when no corresponding acoustical data were obtainable are not considered. Only 26% to 53% of the samples contain sufficient adrenaline to be detected. Maximum flux rates > 3 ng/min occur as rare singular values regardless of noise events. Samples from nights of Leq class > 42 dB, the highest noise class measured at all in the field, show the lowest detection percentages and even the lowest maximum values of adrenaline excretion.

Statistical evaluation fails due to too many missing values.

3.2.2 Noradrenaline

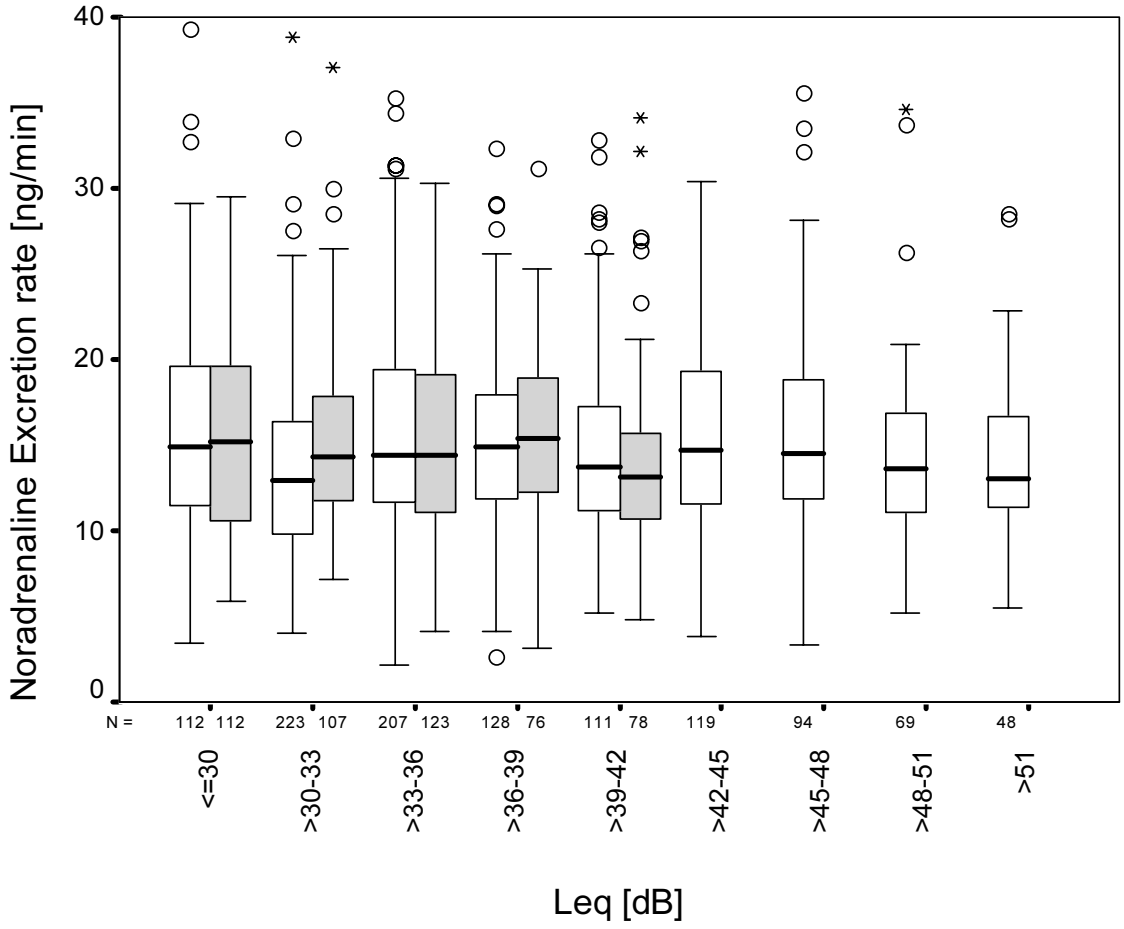

Figure 3.25: Box plot of the noradrenaline excretion rates in all night urine samples during both laboratory (light boxes) and field (grey boxes) studies depending on Leq classes during the nights. Laboratory studies comprise experimental groups only, with nights 2 – 11, field studies with nights 2 - 9. N refers to the number of investigated nights.

Figure 3.25 shows the box plots of nocturnal urinary noradrenaline excretion rates depending on the Leq level during the nights. Shown are the results of the experimental groups in the laboratory without nights 1, 12, and 13 having been adaptation and recovery nights without aircraft noise. Baseline night 2 was also noise free (≤ 30 dB). The results are given in light boxes. The results from the field studies are indicated in grey boxes. Here, the first night is omitted as adaptation night.

Normal range for noradrenaline excretion in urine (adults, HPLC method) is 10 – 55 ng/min [calculated from 24 h excretion, Tietz 1995].

The F-test applied to the data of the laboratory experimental group of 112 subjects shows that at least one of the Leq classes differs statistically significantly from the noradrenaline excretion during baseline nights (F = 13.16 and p = 0.001). The mixed model estimates for noradrenaline excretions during the baseline nights a mean ± SE = 16.1 ± 0.5 ng/min and for the pooled data of noisy nights a lower mean ± SE = 14.9 ± 0.5 ng/min. Post-hoc tests shown in Table 3.25 reveal that the noradrenaline excretion rates in Leq classes 30 ≤ 33 dB (14.8 ± 0.5 ng/min), 33 ≤ 36 dB (14.7 ± 0.5 ng/min), 39 ≤ 42 dB (14.8 ± 0.6 ng/min) 48 ≤ 51 dB (14.6 ± 0.6 ng/min), and > 51 dB (13.9 ± 0.8 ng/min) are significantly lower than in the baseline group Leq ≤ 30 dB. A univariable regression analysis indicates a statistically non significant and irrelevant increase of the noradrenaline excretion rate depending on Leq (p = 0.895; 0.002 ng/min per 1 dB increase Leq).

The F-test applied to the data of the field group of 64 subjects states that there is no significant difference in noradrenaline excretions during reference nights with an Leq ≤ 30 dB compared to pooled data of nights with Leq > 30 dB (F = 0.04 and p = 0.836) The mixed model estimates for noradrenaline excretions during the quiet nights a mean ± SE = 15.1 ± 0.7 ng/min and for the pooled data of nights with Leq > 30 dB a mean ± SE = 15.2 ± 0.6 ng/min. A univariable regression analysis indicates a statistically non significant and irrelevant decrease of the noradrenaline excretion rate depending on Leq (p = 0.640; -0.02 ng/min per 1 dB increase Leq).

There is no significant difference between nocturnal noradrenaline excretion rates in the laboratory and the field (F = 1.96 and p = 0.161). The estimated mean excretion rates are in the laboratory studies ± SE

= 14.9 ± 0.4 ng/min, and in the field studies ± SE = 15.4 ± 0.4 ng/min (Figure 3.26).

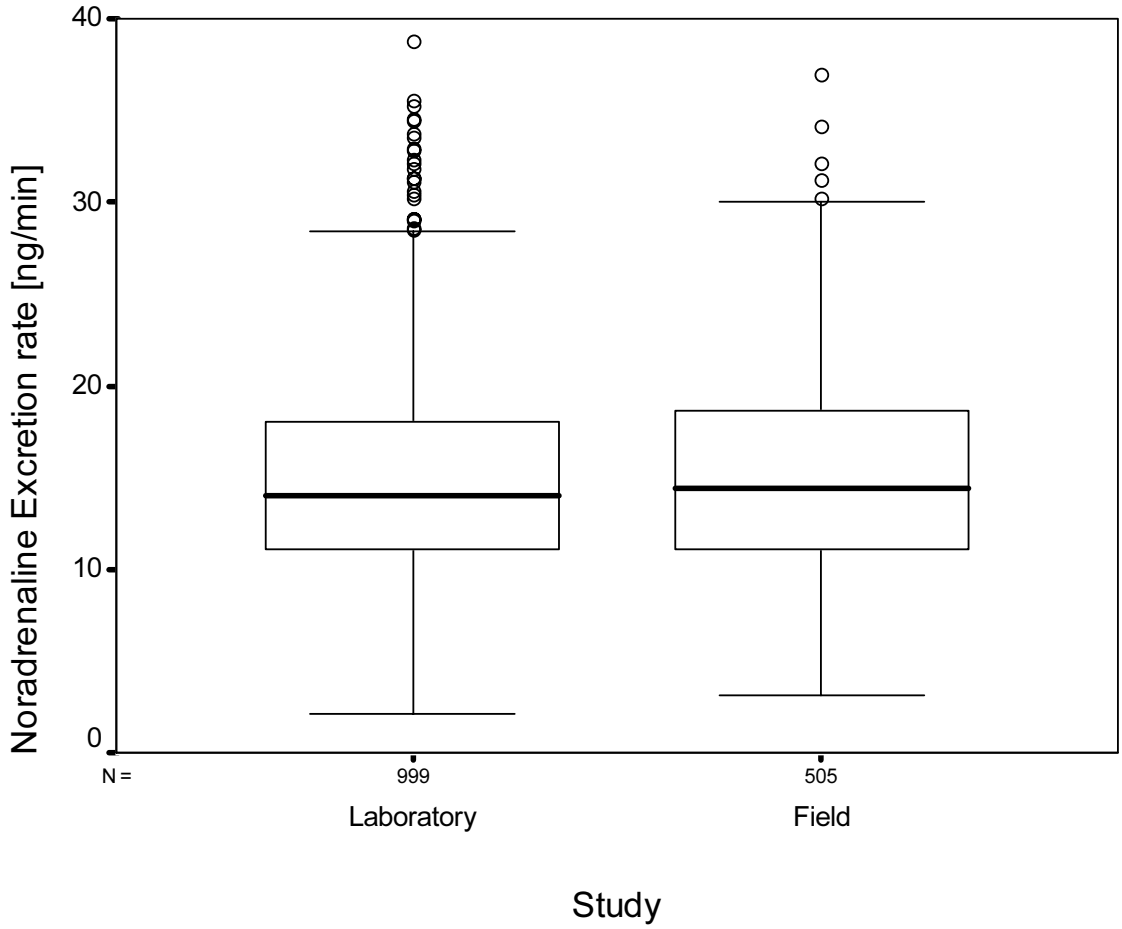

Figure 3.26: Box plot of the noradrenaline excretion rates in all night urine samples during laboratory experimental studies (nights 2 – 11) and field studies (nights 2 – 9). N refers to the number of investigated nights.

20 subjects participated in both the laboratory and the field studies. The F-test applied to the data of this group shows that there is no relevant or significant difference in nocturnal noradrenaline excretions between the studies (F = 0.08 and p = 0.774). The mixed model estimates for the pooled data of noradrenaline excretions of these 20 subjects in the laboratory environment a mean ± SE = 14.2 ± 1.1 ng/min and for the data in the field, at their homes, a mean ± SE = 14.7 ± 1.1 ng/min (Figure 3.27).

Leq classes	Estimated mean ± SE [ng/min]	Adjusted p-value
≤ 30 dB	16.1 ± 0.5	Reference
30≤33 dB	14.8 ± 0.5	**0.008**
33≤36 dB	14.7 ± 0.5	**0.007**
36≤39 dB	14.9 ± 0.5	0.062
39≤42 dB	14.8 ± 0.6	**0.034**
42≤45 dB	15.5 ± 0.5	0.707
45≤48 dB	15.3 ± 0.6	0.545
48≤51 dB	14.6 ± 0.6	**0.040**
> 51 dB	13.9 ± 0.8	**0.013**

Table 3.25: Estimated mean noradrenaline excretion rates (± SE) in all night urine samples during laboratory studies depending on Leq classes during these nights, and their corresponding adjusted p-values with Leq class ≤ 30 dB serving as reference. Significance $p < 0.05$ in bold.

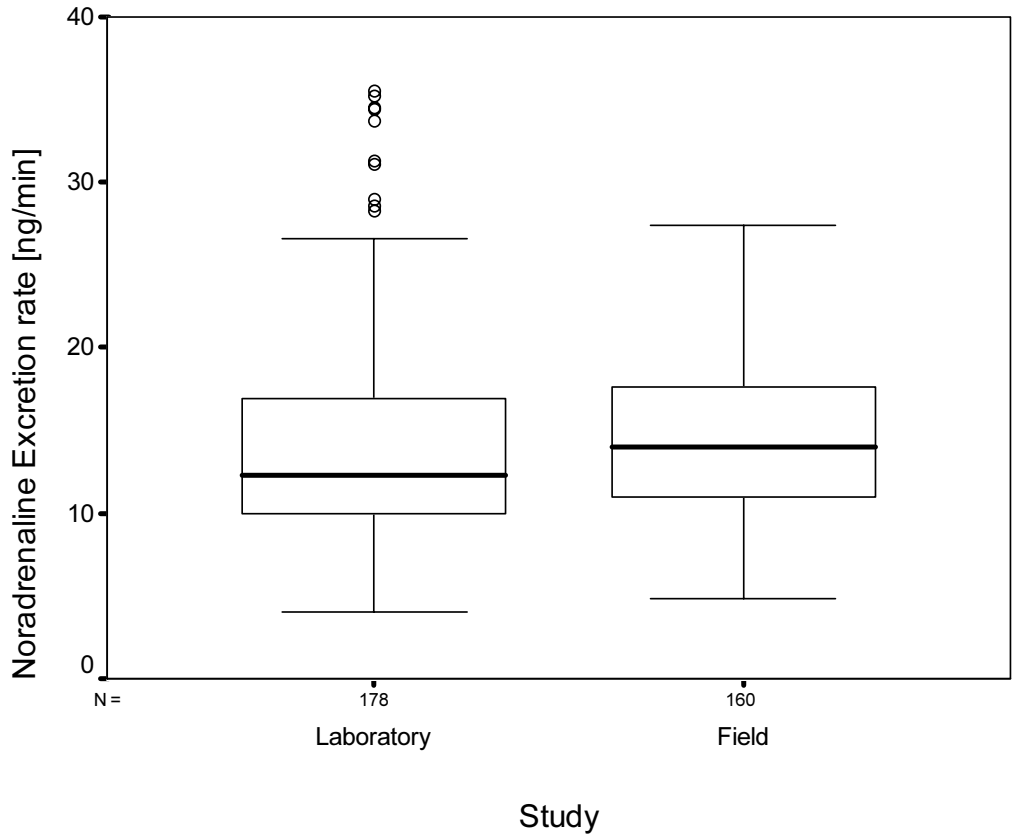

Figure 3.27: Box plot of the noradrenaline excretion rates in all night urine samples during both laboratory and field studies of 20 identical subjects investigated in both studies. Laboratory studies comprise experimental groups only, with noisy nights 3 - 11, field studies with nights 2 - 9. N refers to the number of investigated nights.

The box plots of Figure 3.28 and Figure 3.29 indicate the nocturnal noradrenaline excretion rates in the laboratory studies with both increasing SPLs and increasing numbers of ANEs. The mixed model regression analysis (Table 3.26) indicates a statistically non significant and irrelevant influence of the number of ANEs and the maximum SPL on the noradrenaline excretion. There is no significant interaction between ANE and SPL (p = 0.991).

Variable	β	p-value
Maximum SPL	0.00643	0.612
Number of ANE	-0.00493	0.162

Table 3.26: Mixed model regression calculation of nocturnal noradenaline excretion rates and its statistical dependency on maximum SPL and number of ANE.

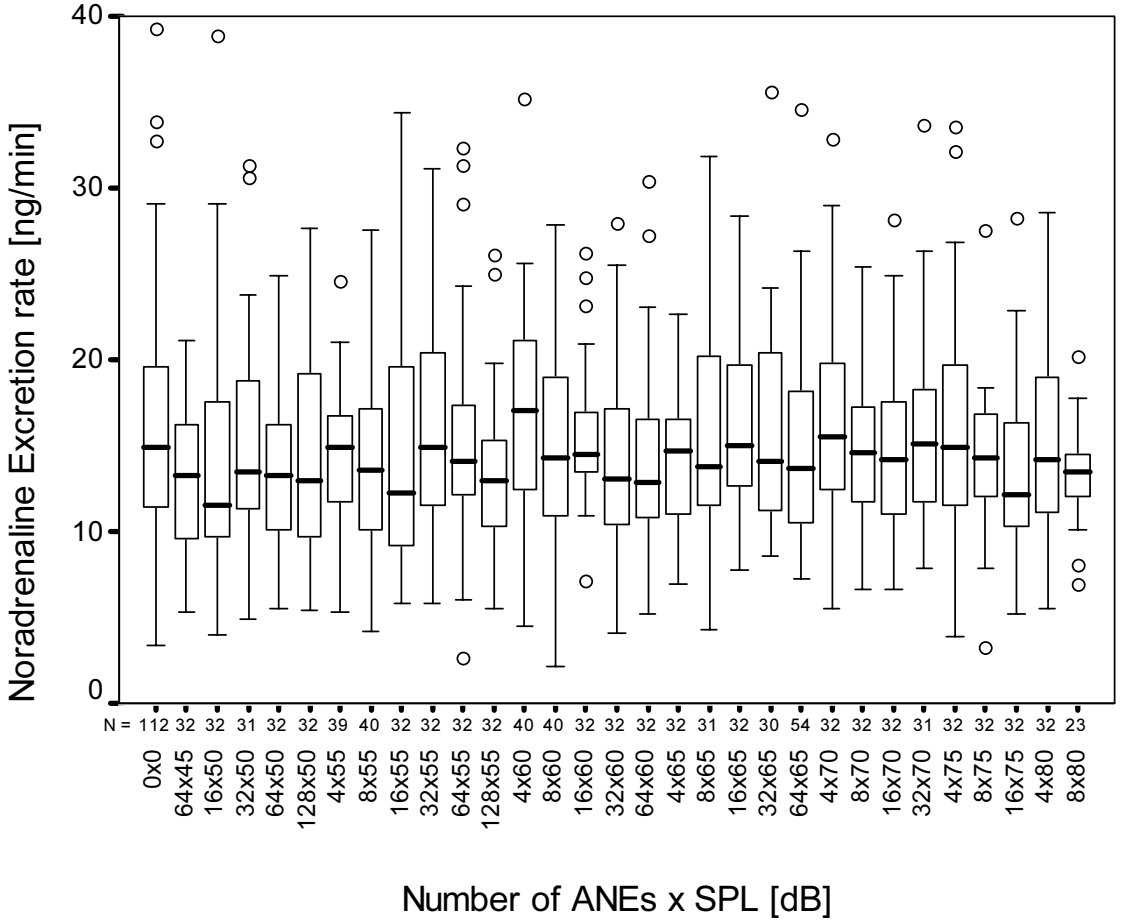

Figure 3.28: Box plot of the noradrenaline excretion rates in all night urine samples during laboratory studies depending on increasing numbers of aircraft noise events (ANE) and corresponding SPL during the nights. Laboratory studies comprise experimental groups only, with nights 2 – 11. N refers to the number of investigated nights.

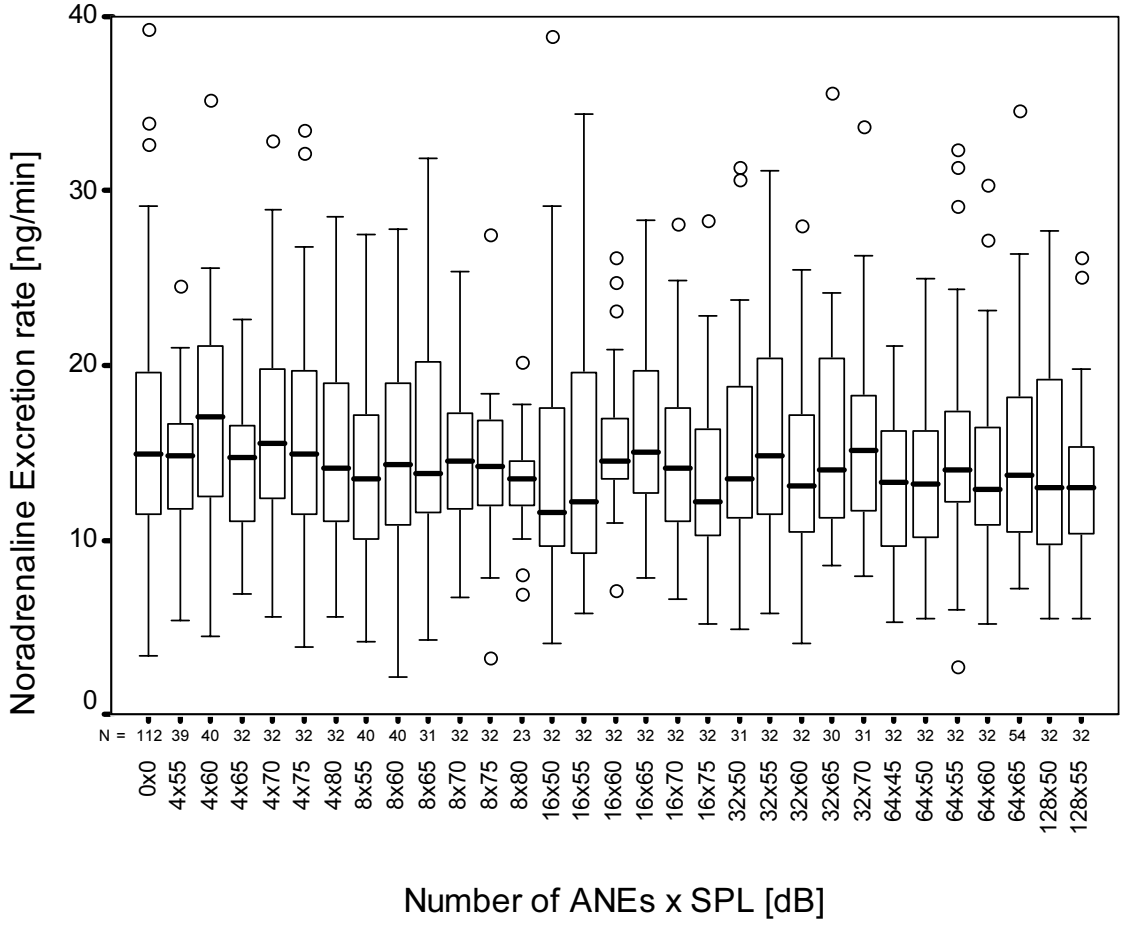

Figure 3.29: Box plot of the noradrenaline excretion rates in all night urine samples during laboratory studies depending on number of aircraft noise events (ANE) and corresponding increasing SPL during the nights. Laboratory studies comprise experimental groups only with nights 2 – 11. N refers to the number of investigated nights.

Table 3.27 illustrates in detail the statistical evaluation of noradrenaline excretion rates and their dependency on all interactions of maximum SPL and number of ANE per night. According to mixed model calculations noradrenaline excretion rates are significantly lower than the baseline rate (16.1 ± 0.5 µmol/min) during nights when 4 ANE at 65 dB (mean ± SE = 13.6 ± 0.8 ng/min, $p = 0.013$) and 16 ANE at 75 dB (mean ± SE = 13.5 ± 0.8 ng/min, $p = 0.006$) were applied.

Maximum SPL LAS,max in dB	Number of Aircraft Noise Events per night					
	4	**8**	**16**	**32**	**64**	**128**
45					14.4±0.8 p=0.370	
50			15.2±0.8 p=0.998	15.0±0.8 p=0.977	14.4±0.8 p=0.320	14.3±0.8 p=0.258
55	15.4±0.7 p=1.000	15.3±0.7 p=0.996	14.0±0.8 p=0.072	14.6±0.8 p=0.520	15.0±0.8 p=0.953	14.0±0.8 p=0.095
60	15.0±0.7 p=0.938	14.3±0.7 p=0.137	14.9±0.8 p=0.919	14.9±0.8 p=0.881	15.3±0.8 p=1.000	
65	**13.6±0.8** **p=0.013**	15.7±0.8 p=1.000	16.0±0.8 p=1.000	14.2±0.8 p=0.209	14.9±0.7 p=0.678	
70	15.8±0.8 p=1.000	14.5±0.8 p=0.415	15.1±0.8 p=0.982	14.9±0.8 p=0.937		
75	16.3±0.8 p=1.000	15.0±0.8 p=0.933	**13.5±0.8** **p=0.006**			
80	15.7±0.8 p=1.000	14.4±0.9 p=0.624				

Table 3.27: Estimated mean noradrenaline excretion rates (± SE) [ng/min] in all night urine samples during **experimental** laboratory studies (n = 112) depending on all combinations of maximum SPL and number of ANEs per night applied and their corresponding adjusted p-values with noise free (0x0) night # 2 (estimated mean ± SE = 16.1 ± 0.5 ng/min) serving as reference. Significance $p < 0.05$ in bold.

Figure 3.30 illustrates the noradrenaline excretion rates at night during field studies in dependency on the number of traffic noise events per night. None of the exposure categories differs statistically significantly from the overall mean ($F = 1.16$ and $p = 0.326$). There is no dose-response relationship. A mixed model regression analysis (Table 3.26) indicates a statistically non significant and irrelevant influence of the number of traffic noise events per night and L_{eq} on the noradrenalin excretion. There is no significant interaction between L_{eq} and number of traffic noise events ($p = 0.723$).

Variable	β	p-value
Leq	-0.02311	0.668
Number of Traffic Noise Events per Night	-0.00103	0.839

Table 3.28: Mixed model regression calculation of nocturnal noradrenaline excretion rates and its statistical dependency on Leq and number of traffic noise events per night.

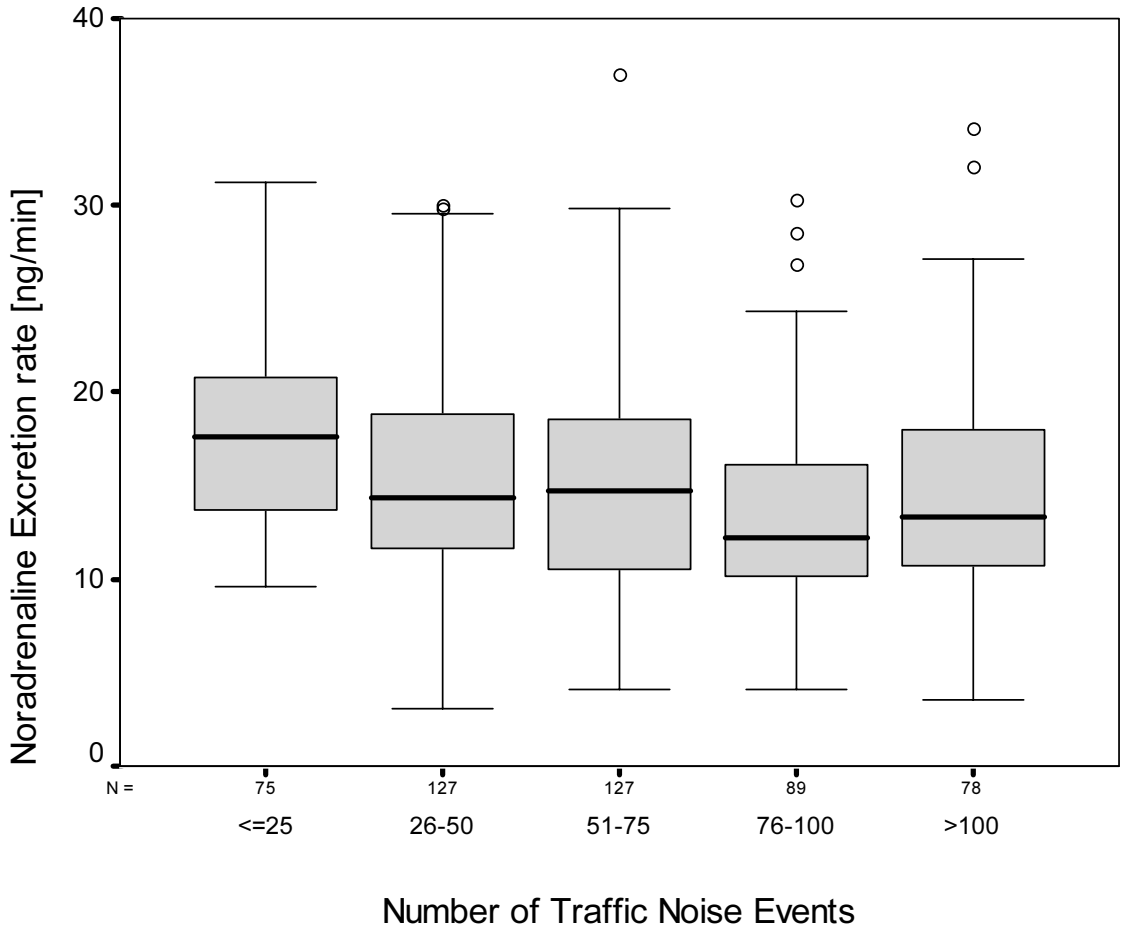

Figure 3.30: Box plot of the noradrenaline excretion rates in all night urine samples during field studies depending on number of traffic noise events during the nights. Field studies comprise all nights 2 – 9. N refers to the number of investigated nights.

Figure 3.31 and Figure 3.32 show in box plots the noradrenaline excretion rates in the laboratory studies comparing experimental and control groups, as well as in the field studies in dependency on the experimental night. In

the control group, none of the exposure nights 1 – 13 differs statistically significantly from the overall mean (F-test: F = 0.73 and p = 0.716).

In the laboratory experimental group, the result of the F-test indicates that at least one of the experiment nights differs statistically significantly from the overall mean (F = 2.17 and p = 0.011). Post-hoc tests shown in Table 3.29 reveal that the noradrenaline excretion rates during nights #5, #6 , #8, #9, #10 are significantly lower than that one during reference night #2 (16.1 ± 0.5 ng/min). None of the other nights, including adaptation and last night, differs significantly from the reference night. A univariable mixed model regression analysis indicates a statistically non significant and irrelevant decrease of the noradrenaline excretion rate depending on the experimental night (p = 0.119; -0.06 ng/min per experimental night increase).

In the field group, the result of the F-test indicates that at least one of the experiment nights differs statistically significantly from the overall mean (F = 1.97 and p = 0.048). Post-hoc tests as shown in Table 3.30 reveal, however, that none of the excretion rates differs statistically significantly from that one in the reference night #2. A univariable regression analysis indicates a statistically non significant and irrelevant decrease of the noradrenaline excretion rate depending on the experimental night (p = 0.437; -0.05 ng/min per experimental night increase).

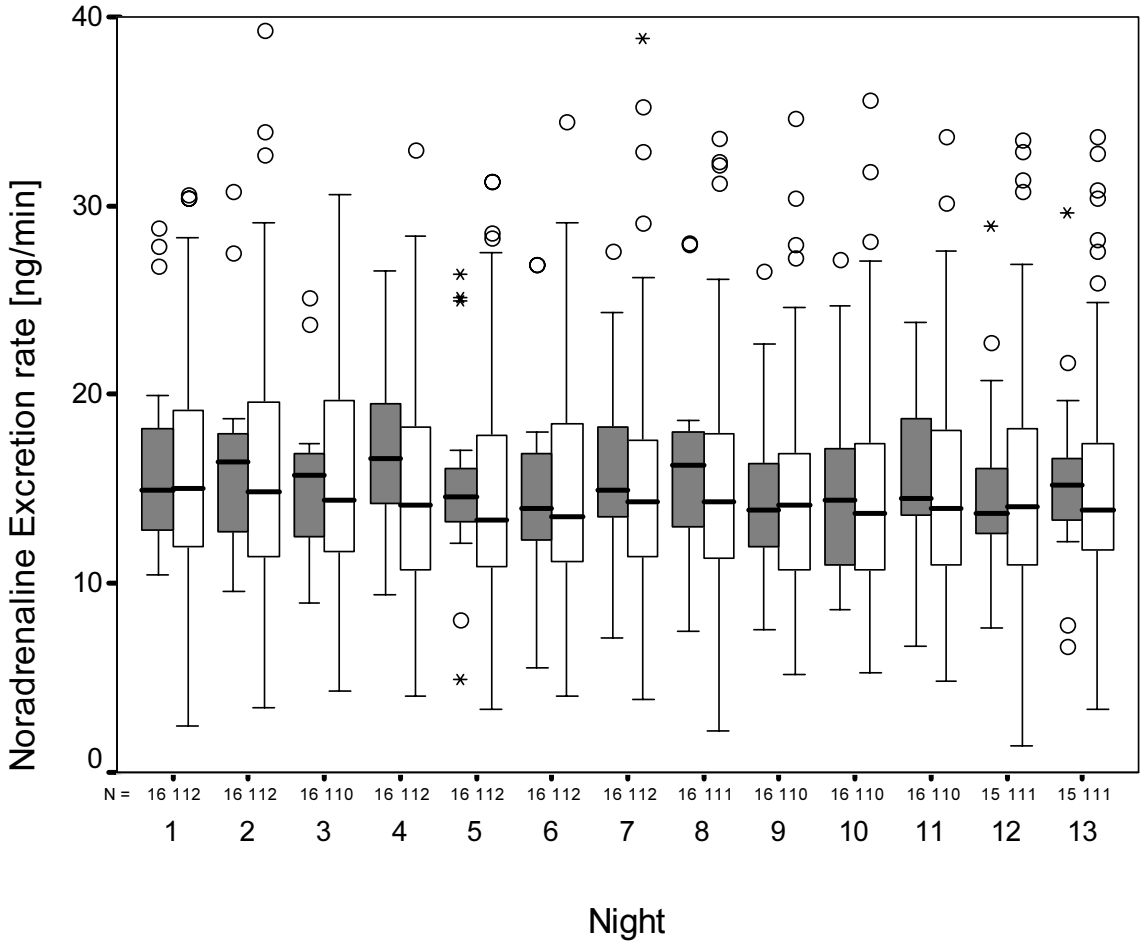

Figure 3.31: Box plot of the noradrenaline excretion rates in all night urine samples in both control group (grey boxes, 16 subjects) and experimental group (light boxes, 112 subjects) during the laboratory studies depending on the consecutive experimental nights. First nights were always Monday/Tuesday nights. N refers to the number of investigated nights.

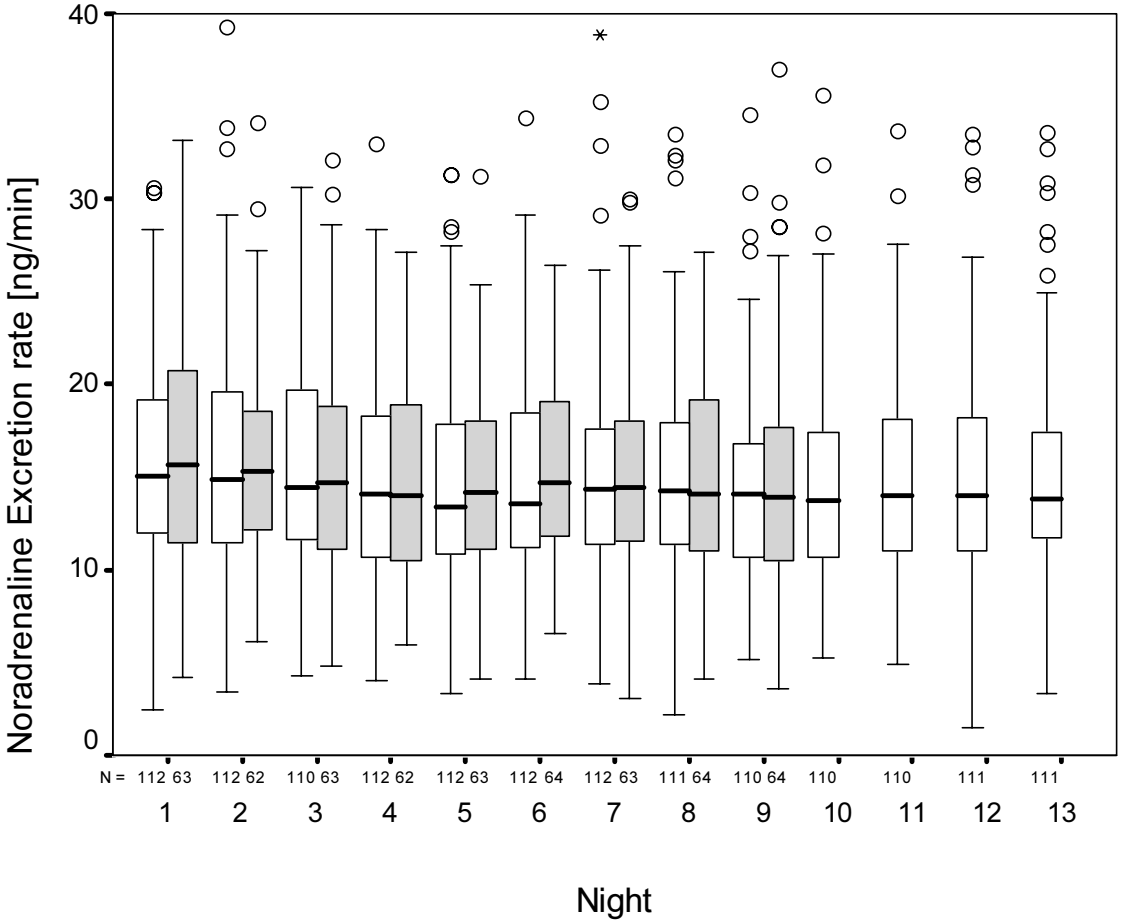

Figure 3.32: Box plot of the noradrenaline excretion rates in all night urine samples during both experimental group in laboratory studies (light boxes, 112 subjects) and in the field studies (grey boxes, 64 subjects) depending on the consecutive experimental nights. First nights were always Monday/Tuesday nights. N refers to the number of investigated nights.

Night	Estimated mean ± SE [ng/min]	Adjusted p-value
Night #1	15.7 ± 0.5	0.976
Night #2	16.1 ± 0.5	Reference
Night #3	15.6 ± 0.6	0.960
Night #4	14.9 ± 0.5	0.085
Night #5	14.6 ± 0.5	**0.011**
Night #6	14.7 ± 0.5	**0.024**
Night #7	15.1 ± 0.5	0.218
Night #8	14.8 ± 0.6	**0.049**
Night #9	14.5 ± 0.6	**0.006**
Night #10	14.6 ± 0.6	**0.013**
Night #11	15.0 ± 0.6	0.153
Night #12	15.0 ± 0.6	0.141
Night #13	15.2 ± 0.6	0.298

Table 3.29: Estimated mean noradrenaline excretion rates (± SE) in all night urine samples during laboratory studies, experimental group (n = 112) depending on experimental night and their corresponding adjusted p-values with night #2 serving as reference. Significance $p < 0.05$ in bold.

Night	Estimated mean ± SE [ng/min]	Adjusted p-value
Night #1	16.6 ± 0.7	0.971
Night #2	16.1 ± 0.7	Reference
Night #3	15.2 ± 0.7	0.646
Night #4	14.7 ± 0.7	0.158
Night #5	14.6 ± 0.7	0.129
Night #6	15.5 ± 0.7	0.950
Night #7	15.1 ± 0.7	0.492
Night #8	15.4 ± 0.7	0.817
Night #9	15.0 ± 0.7	0.446

Table 3.30: Estimated mean noradrenaline excretion rates (± SE) in all night urine samples during field studies (n = 64) depending on experimental night and their corresponding adjusted p-values with night #2 serving as reference. Significance $p < 0.05$ in bold.

Figure 3.33 shows in box plots the nocturnal noradrenaline excretion rates in the laboratory and field studies during noisy nights excluding adaptation and recovery nights. Compared are the flux rates in dependency on the weekday. Neither in the laboratory experimental group of 112 subjects (F-test: $F = 0.84$ and $p = 0.535$) nor in field group of 64 subjects (F-test: $F = 0.91$ and $p = 0.485$) any weekday differs statistically significantly from the overall mean noradrenaline excretion rate.

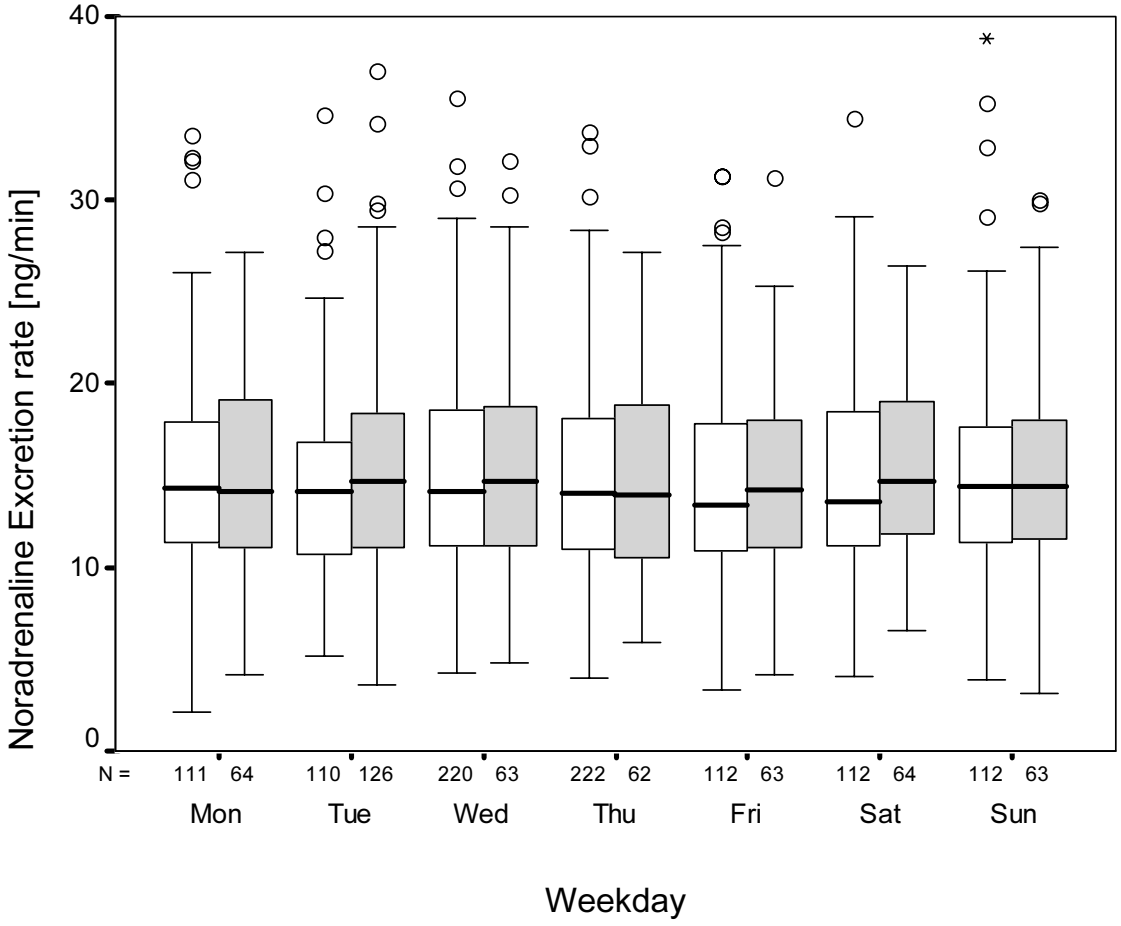

Figure 3.33: Box plot of the noradrenaline excretion rates in all night urine samples during both experimental laboratory studies (light boxes, noisy nights 3 – 11, 112 subjects) and field studies (grey boxes, noisy nights 2 – 9, 64 subjects) depending on the appropriate weekday nights. First nights (excluded) were always Monday/Tuesday nights. N refers to the number of investigated nights.

Figure 3.34 illustrates in box plots the noradrenaline excretion rates at night in both the laboratory experimental and the field studies and their dependency from gender. F-tests show that there is no statistically different excretion rate between genders under laboratory conditions ($F = 0.04$ and $p = 0.837$, excretion rate in males mean ± SE = 14.9 ± 0.7 ng/min, and in females 15.1 ± 0.6 ng/min). Under field conditions the appropriate results are: $F = 1.82$ and $p = 0.182$, excretion rate in males mean ± SE = 16.1 ± 0.9 ng/min, and in females 14.5 ± 0.8 ng/min.

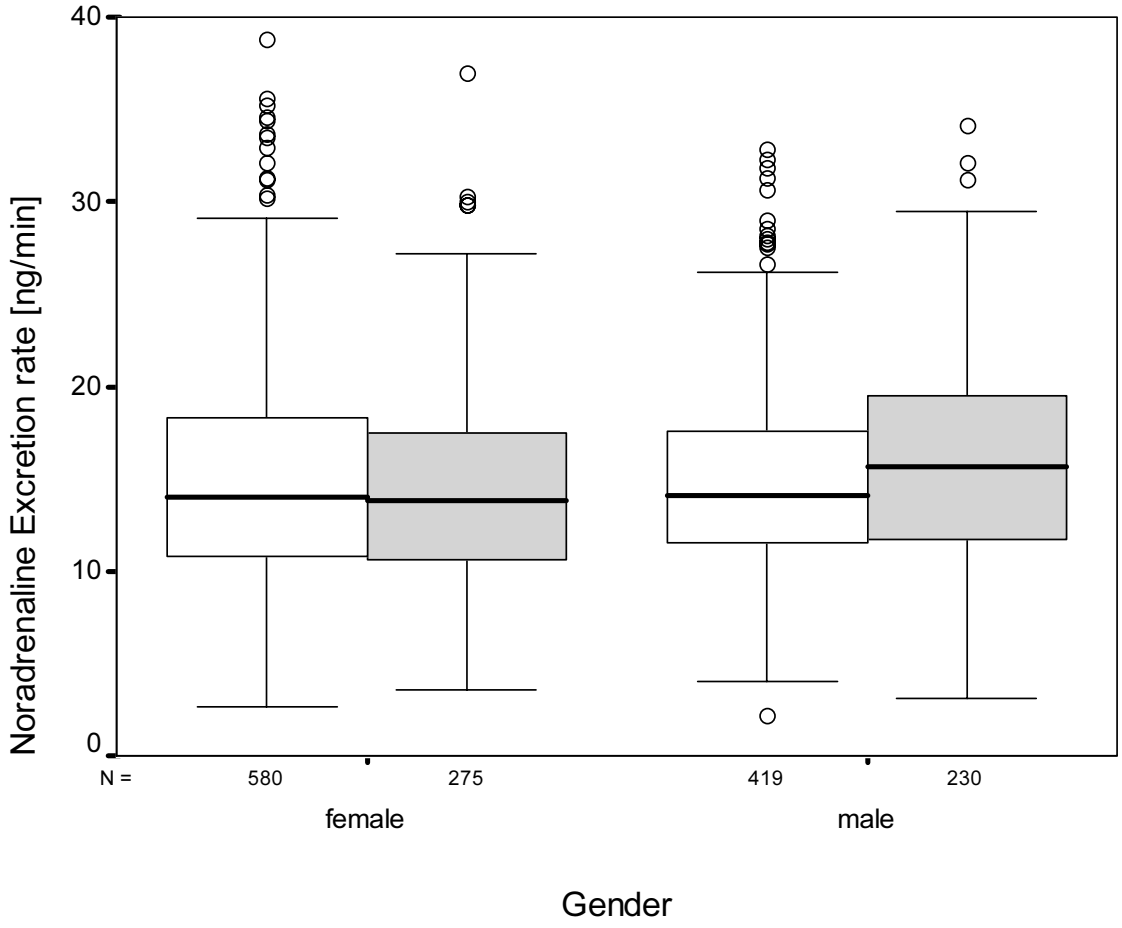

Figure 3.34: Box plot of the noradrenaline excretion rates in all night urine samples during both experimental laboratory studies (light boxes, noisy nights 3 – 11, 112 subjects) and field studies (grey boxes, noisy nights 2 – 9, 64 subjects) depending on the gender. N refers to the number of investigated nights.

The closest fit to an equal age distribution among the participants (in laboratory studies: mean ± SD = 38 ± 13 years and in field studies: 37 ± 13 years) leads to six categories according to Table 3.31.

Age range (years)	Subjects (lab) (n = 128)	Subjects (field) (n = 64)
18 - 25	25 (19.5%)	16 (25.0%)
26 - 33	35 (27.3%)	9 (14.1%)
34 - 41	18 (14.1%)	13 (20.3%)
42 - 49	19 (14.8%)	15 (23.4%)
50 - 57	17 (13.3%)	6 (9.4%)
58 - 65	14 (10.9%)	5 (7.8%)

Table 3.31: Age distribution over six categories with a category width of 8 years in laboratory and field studies.

Figure 3.35 shows the box plots of nocturnal urinary noradrenaline excretion rates depending on the age class. Shown are the results of the experimental groups in the laboratory, noisy nights 3 – 11 only (light boxes), and of the field group, nights 2 – 9 only, excluding the adaptation night (grey boxes).

The F-test applied to the data of the laboratory experimental group of 112 subjects shows that there is no significant difference in any age class with respect to noradrenaline excretions ($F = 1.49$ and $p = 0.199$). A univariable regression analysis indicates a statistically non significant and irrelevant increase of the noradrenaline excretion rate depending on age ($p = 0.368$; 0.03 ng/min per year increase).The F-test applied to the data of the field group of 64 subjects states that at least one age class differs from the overall mean of nocturnal noradrenaline excretion ($F = 2.42$ and $p = 0.047$). Post-hoc tests, however shown in Table 3.32, indicate that noradrenaline

flux in age class 18 – 25 years does not differ statistically from all other classes. A univariable regression analysis indicates a statistically significant increase of the noradrenaline excretion rate depending on age (p = 0.045; 0.09 ng/min per year increase).

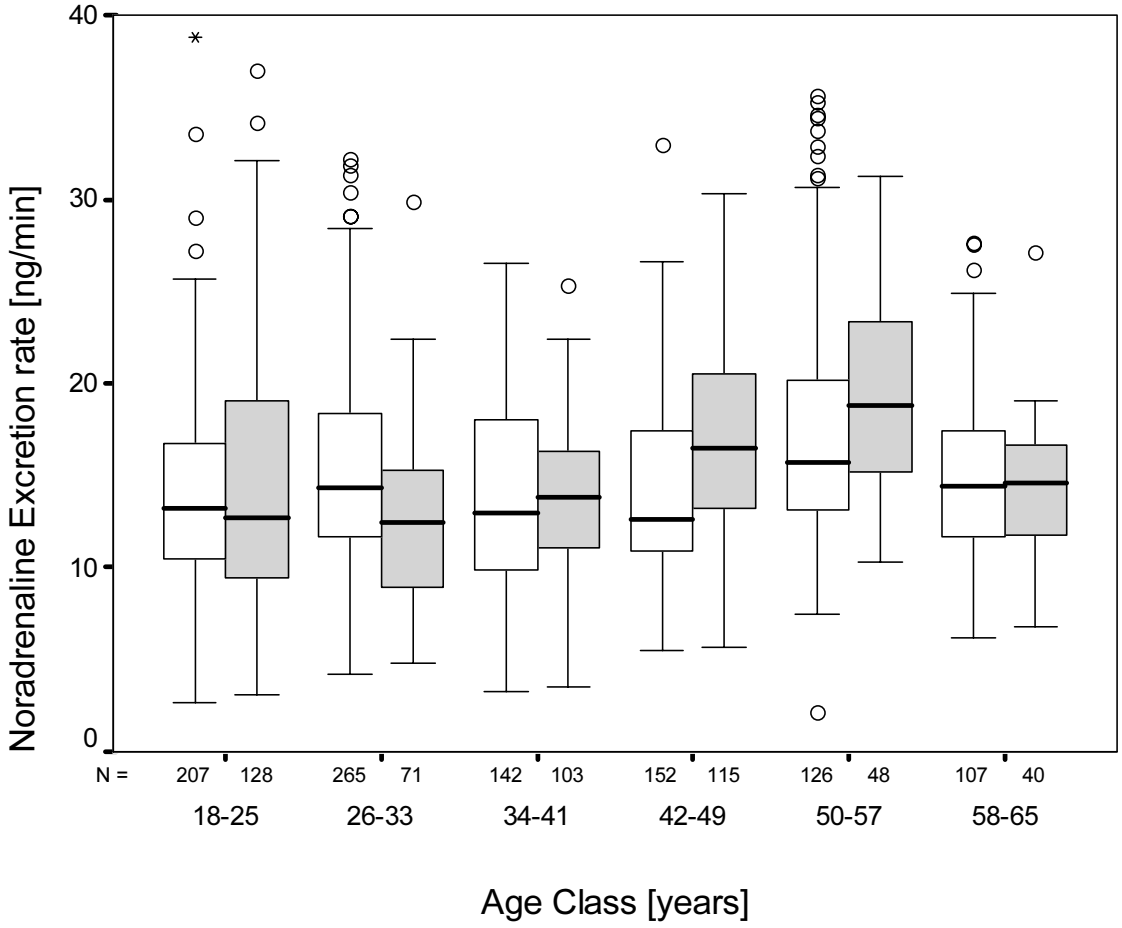

Figure 3.35: Box plot of the noradrenaline excretion rates in all night urine samples during both experimental laboratory studies (light boxes, noisy nights 3 – 11, 112 subjects) and field studies (grey boxes, noisy nights 2 – 9, 64 subjects) depending on the age class. N refers to the number of investigated nights.

Age range (years)	Estimated noradrenaline mean ± SE (ng/min)	Adjusted p-value
18 - 25	14.3 ± 1.1	Reference
26 - 33	13.0 ± 1.5	0.955
34 - 41	13.8 ± 1.2	0.999
42 - 49	17.3 ± 1.2	0.257
50 - 57	19.2 ± 1.8	0.116
58 - 65	14.5 ± 2.0	1.000

Table 3.32: Estimated mean noradrenaline excretion rates (± SE) in all night urine samples during field studies depending on age classes during these nights, and their corresponding adjusted p-values with age class 18 – 25 years serving as reference. Significance $p < 0.05$ in bold.

Figure 3.36 and Figure 3.37 show in box plots the noradrenaline excretion rates depending on the subjects' noise sensitivity and their pre-annoyance level to aircraft noise. Shown are the results of the experimental groups in the laboratory without nights 1, 2, 12, and 13 having been adaptation, baseline and recovery nights without aircraft noise. The results are given in light boxes. The results from the field studies are indicated in grey boxes. Here, the first night is excluded as adaptation night. The categories of noise sensitivity range from "very low" to "very high", respectively of the pre-annoyance level from "not annoyed" to "very annoyed". Their construction and psychological consideration with respect to nocturnal aircraft noise are reported in detail by Quehl [2004].

The F-test applied to the data of the laboratory experimental group of 112 subjects shows that there is no significant difference in noradrenaline excretions between the categories of noise sensitivity ($F = 0.43$ and $p = 0.787$). A univariable regression analysis indicates a statistically non significant and irrelevant decrease of the noradrenaline excretion rate depending on noise sensitivity ($p = 0.402$; -0.46 ng/min per 1 noise sensitivity level increase).The F-test applied to the data of the field group of 64 subjects states also that there is no relevant or significant difference in noradrenaline excretions between the noise sensitivity classes ($F = 1.75$ and $p = 0.167$). A univariable

regression analysis indicates a statistically non significant and irrelevant decrease of the noradrenaline excretion rate depending on noise sensitivity ($p = 0.762$; -0.25 ng/min per 1 noise sensitivity level increase).

The appropriate F-tests applied to the data regarding the pre-annoyance level of the subjects give similar results, namely for both the laboratory experimental and the field group there is no significant difference in noradrenaline excretions between the levels of pre-annoyance to aircraft noise (laboratory: $F = 0.87$ and $p = 0.485$; field: $F = 0.33$ and $p = 0.857$). The univariable regression analyses indicate statistically non significant and irrelevant changes of the noradrenaline excretion rate depending on pre-annoyance level (in the laboratory $p = 0.690$; -0.17 ng/min per 1 pre-annoyance unit increase, and in the field $p = 0.980$; 0.02 ng/min per 1 pre-annoyance unit increase).

Mixed model regression analyses for the laboratory experimental group (Table 3.41 and Table 3.45) that take several variables such as L_{eq} , number of ANEs per night and maximum SPL plus confounders like gender, age and noise sensitivity into account simultaneously, indicate statistically non significant and irrelevant influences of all of them on the noradrenaline excretion.

Table 3.35 shows the mixed model regression analysis for the appropriate variables from the field study. Here, merely the subject's age is of statistically significant influence on the noradrenaline excretion rate.

Variable	β	p-value
Leq	0.00176	0.913
Age	0.03351	0.343
Gender	-0.26560	0.774
Noise Sensitivity	-0.48670	0.375

Table 3.33: Mixed model regression calculation of nocturnal noradrenaline excretion rates in the experimental laboratory group and its statistical dependency on Leq and various confounders.

Variable	β	p-value
Number of ANEs	-0.00495	0.161
Maximum SPL	0.00615	0.627
Age	0.03316	0.348
Gender	-0.24990	0.787
Noise Sensitivity	-0.48510	0.376

Table 3.34: Mixed model regression calculation of nocturnal noradrenaline excretion rates in the experimental laboratory group and its statistical dependency on number of ANEs and max. SPL and various confounders.

Variable	β	p-value
Leq	-0.02800	0.602
Number of Traffic Noise Events	-0.00058	0.909
Age	0.10720	**0.022**
Gender	1.98650	0.093
Noise Sensitivity	-0.67150	0.397

Table 3.35: Mixed model regression calculation of nocturnal noradrenaline excretion rates in the field group and its statistical dependency on Leq and various confounders. Significance $p < 0.05$ in bold.

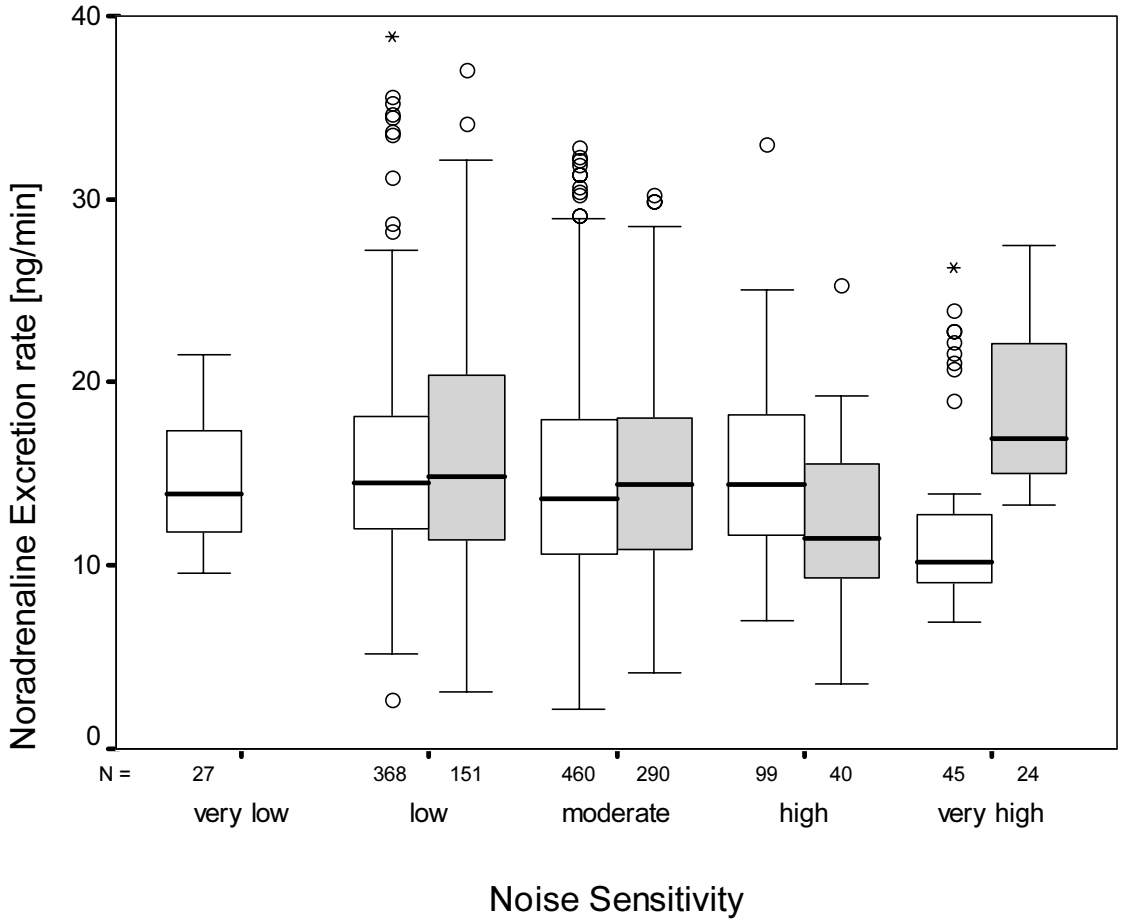

Figure 3.36: Box plot of the noradrenaline excretion rates in all night urine samples during both experimental laboratory studies (light boxes, noisy nights 3 – 11, 112 subjects) and field studies (grey boxes, noisy nights 2 – 9, 64 subjects) depending on the noise sensitivity of the subjects. N refers to the number of investigated nights.

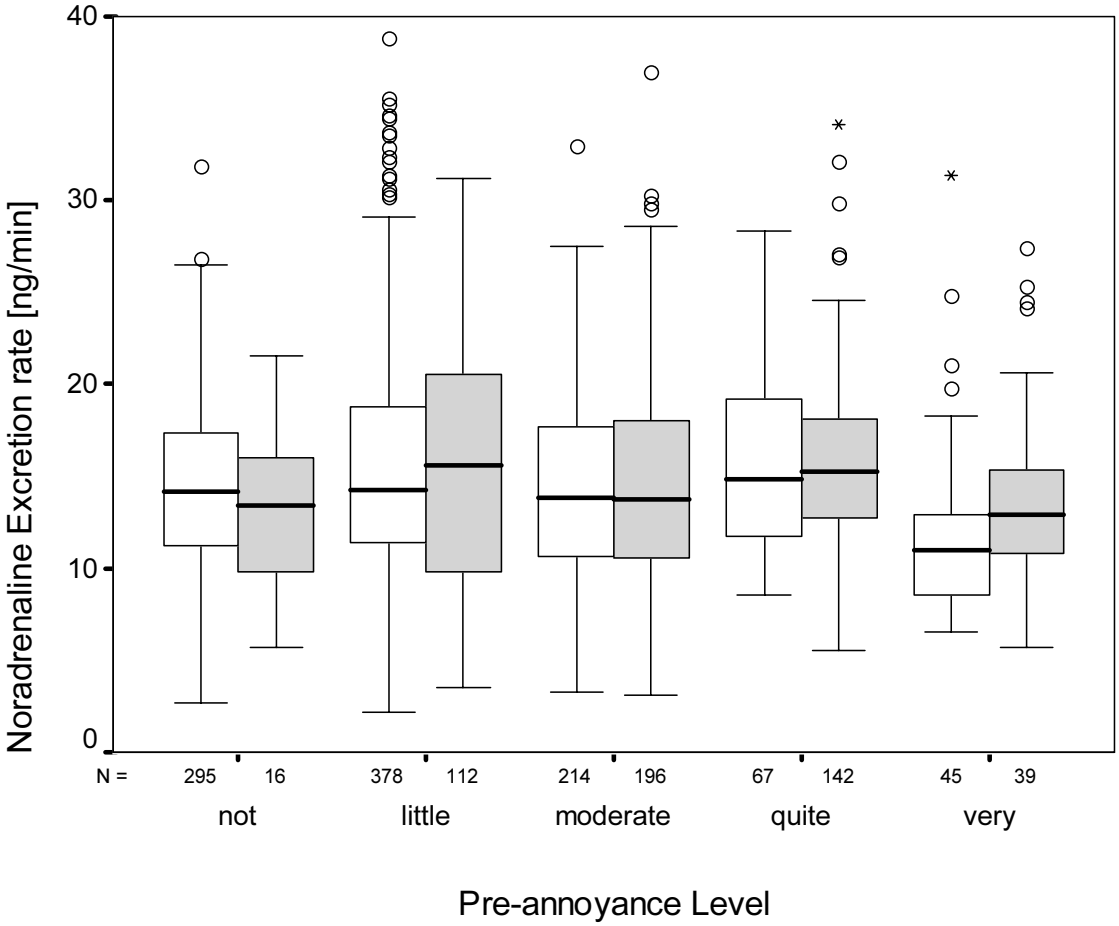

Figure 3.37: Box plot of the noradrenaline excretion rates in all night urine samples during both experimental laboratory studies (light boxes, noisy nights 3 – 11, 112 subjects) and field studies (grey boxes, noisy nights 2 – 9, 64 subjects) depending on the pre-annoyance level to aircraft noise of the subjects. N refers to the number of investigated nights.

3.3 Cortisol

Unfortunately, for the evaluation of free cortisol concentrations a change of methods had occurred during the course of studies. Within study phase STRAIN II an EIA had been introduced by the laboratory running the tests due to temporarily delivery difficulties of the RIA in use. The absolute EIA results could not be re-calculated for the otherwise used RIA. Re-determination of free cortisol by RIA from deep frozen urine samples kept as emergency substitutes several weeks later did not reveal consistent results. Therefore, results of that laboratory study phase in question (STRAIN II) comprising 32 subjects (24 in experimental, and 8 in control group) are neglected when absolute values are taken into account.

Figure 3.38 shows the box plots of nocturnal urinary cortisol excretion rates depending on the L_{eq} level during the nights. Shown are the results of the experimental groups in the laboratory (n = 88) without nights 1, 12, and 13 having been adaptation and recovery nights without aircraft noise. Baseline night 2 was also noise free (≤ 30 dB). The results are given in light boxes. The results from the field studies (n = 48) are indicated in grey boxes. Here, the first night is omitted as adaptation night. Additionally, all those nights are excluded when subjects got up before 6:25 a.m. or after 7:35 a.m. in order to have a comparable group of subjects getting up by 7:00 a.m. ± 35 minutes, since the laboratory group had a firmly set time of 7:00 a.m. for leaving bed. This limitation is necessary to minimize the effect of the well known circadian rhythm of cortisol secretion being most pronounced in the early morning (see also Figure 3.41).

The F-test applied to the data of the laboratory experimental group of 88 subjects shows that there is neither a relevant nor a significant difference in cortisol excretions during baseline nights compared to pooled data of noisy nights ($F = 1.18$ and $p = 0.278$). The mixed model estimates for cortisol excretions during the baseline nights a mean ± SE = 56.5 ± 3.9 ng/min and for the pooled data of noisy nights a mean ± SE = 58.8 ± 3.4 ng/min. A

univariable regression analysis indicates a statistically non significant and irrelevant decrease of the cortisol excretion rate depending on Leq ($p = 0.297$; -0.11 ng/min per 1 dB increase Leq).

The F-test applied to the data of the field group of 48 subjects with get-up times of 7:00 a.m. ± 35 minutes states that there is no relevant or significant difference in cortisol excretions during reference nights with an $L_{eq} \leq 30$ dB compared to pooled data of nights with $L_{eq} > 30$ dB ($F = 0.38$ and $p = 0.540$) The mixed model estimates for cortisol excretions during the quiet nights a mean ± SE = 43.0 ± 3.2 ng/min and for the pooled data of nights with $L_{eq} > 30$ dB a mean ± SE = 41.4 ± 2.4 ng/min. A univariable regression analysis indicates a statistically non significant and irrelevant increase of the cortisol excretion rate depending on Leq ($p = 0.282$; 0.3 ng/min per 1 dB increase Leq).

There is a significant difference between nocturnal cortisol excretion rates in the laboratory and the field (F-test: $F = 24.39$ and $p < 0.001$). The estimated mean excretion rates are in the laboratory studies ± SE = 57.7 ± 2.7 ng/min, and in the field studies ± SE = 45.1 ± 3.1 ng/min). Figure 3.39 shows in box plots the descriptive distribution of cortisol excretion rates in laboratory and field studies.

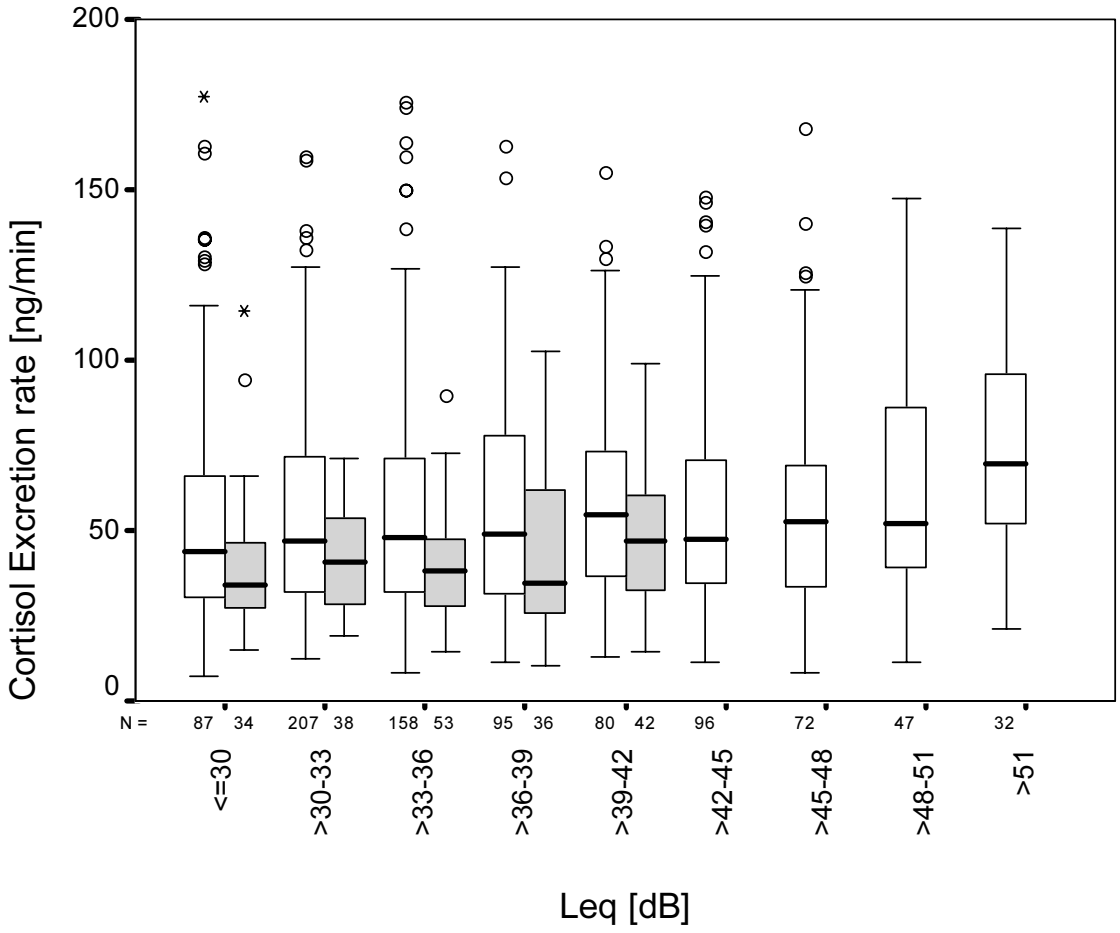

Figure 3.38: Box plot of the cortisol excretion rates in all night urine samples during both laboratory (light boxes) and field (grey boxes) studies depending on Leq classes during the nights. Laboratory studies comprise experimental groups only (n = 88), with nights 2 – 11, field studies with nights 2 – 9 and times getting-up 6:25 a.m. -7:35 a.m. N refers to the number of investigated nights.

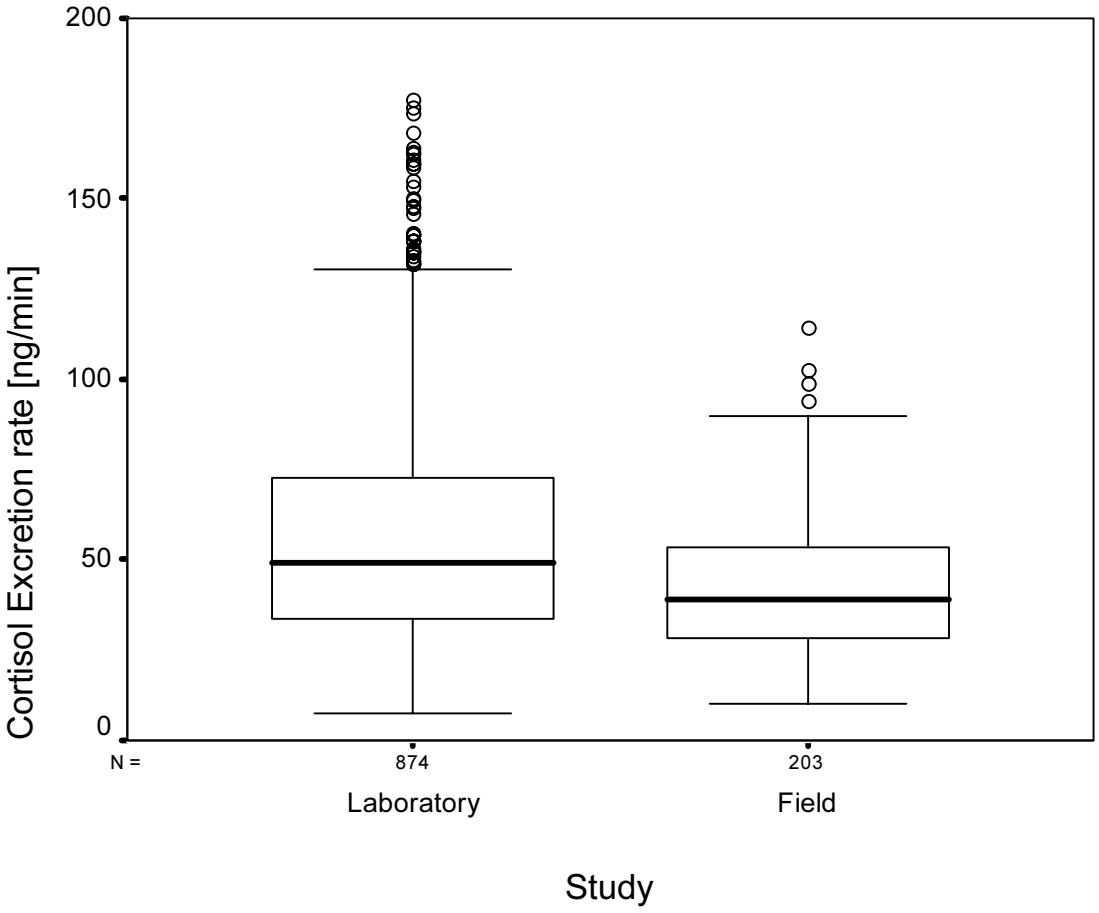

Figure 3.39: Box plot of the cortisol excretion rates in all night urine samples during laboratory experimental studies (n = 88, nights 2 – 11) and field studies (n = 48, nights 2 – 9 and subjects getting up 6:25 a.m. – 7:35 a.m.). N refers to the number of investigated nights.

20 subjects participated in both the laboratory and the field studies. The F-test applied to the data of this group shows that there is no relevant or significant difference in nocturnal cortisol excretions between the studies ($F = 1.45$ and $p = 0.238$). The mixed model estimates for the pooled data of cortisol excretions of these 20 subjects in the laboratory environment a mean ± SE = 47.9 ± 3.6 ng/min and for the data in the field, at their homes, a mean ± SE = 41.2 ± 4.3 ng/min (Figure 3.40).

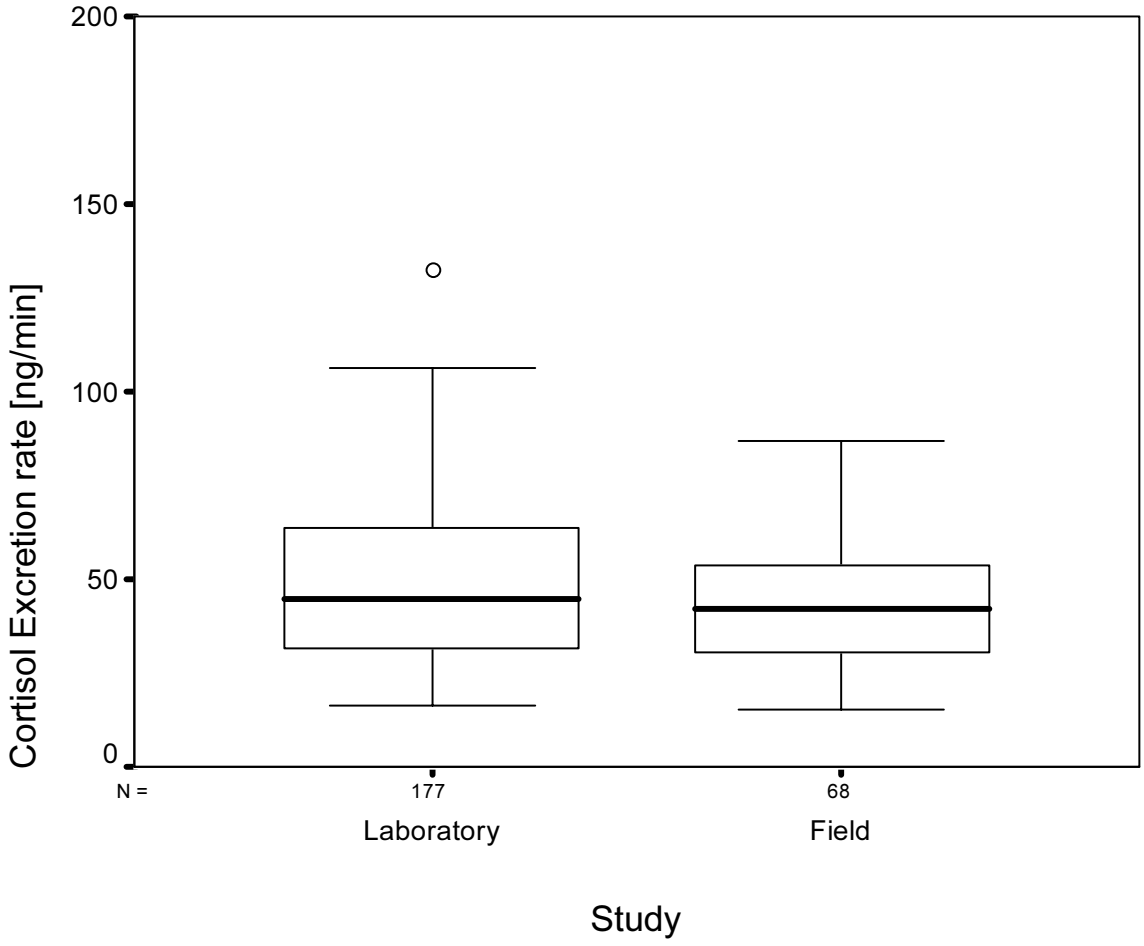

Figure 3.40: Box plot of the cortisol excretion rates in all night urine samples during both laboratory and field studies of 20 identical subjects investigated in both studies. Laboratory studies comprise experimental groups only, with noisy nights 3 – 11, field studies with nights 2 – 9 and times getting-up 6:25 a.m. – 7:35 a.m. N refers to the number of investigated nights.

Figure 3.41 shows in box plots the nocturnal cortisol excretion rates in the field studies including the adaptation night. Compared are the cortisol flux rates in dependency on classes of times getting-up that marked the end of urine collection. This is well illustrating the circadian rhythm of cortisol secretion with its peak in the morning. In the laboratory, the end of night was set to 7:00 a.m for all subjects. In the field studies, it was up to the subjects when they wished to get-up.

The F-test indicates that at least one of the time classes differs from the overall mean ($F = 25.59$ and $p < 0.001$). Post-hoc tests show that cortisol

excretion rates with urine collections ending > 6:30 a.m. differ statistically significantly from the excretion rates < 6:00 a.m. (Table 3.36).

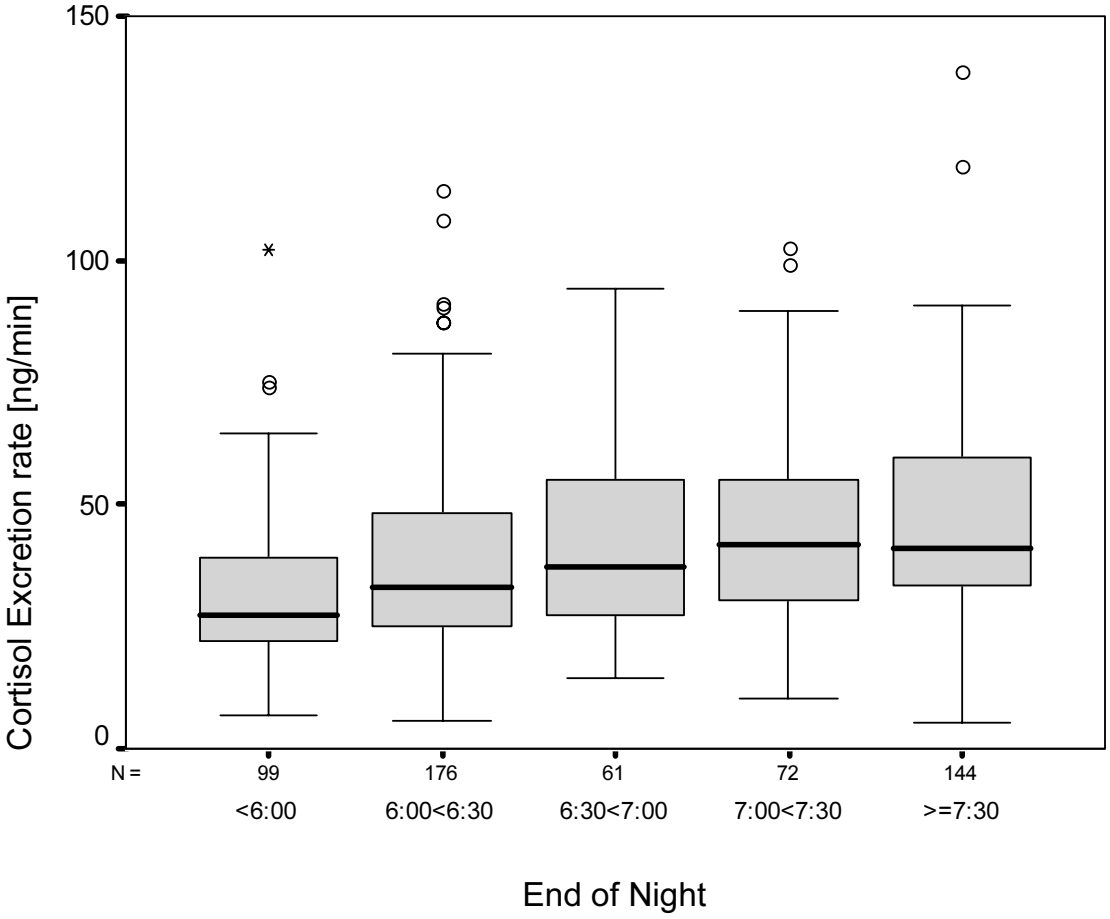

Figure 3.41: Box plot of the cortisol excretion rates in all night urine samples during field studies, nights 1 – 9 (n = 64) depending on time of getting-up, i.e. end of urine collection period. N refers to the number of investigated nights.

End of night time	Estimated mean ± SE [ng/min]	Adjusted p-value
< 06:00	31.8 ± 2.4	Reference
6:00 < 6:30	36.2 ± 2.1	0.071
6:30 < 7:00	39.0 ± 2.6	**0.006**
7:00 < 7:30	43.7 ± 2.5	**0.001**
> 7:30	50.8 ± 2.2	**0.001**

Table 3.36: Estimated mean cortisol excretion rates (± SE) in all night urine samples during field studies (n = 64) depending on times of getting up and their corresponding adjusted p-values with time < 6:00 a.m. serving as reference. Significance p < 0.05 in bold.

The box plots of Figure 3.42 and Figure 3.43 illustrate the nocturnal cortisol excretion rates in the laboratory studies with both increasing SPLs and increasing numbers of ANEs. The mixed model regression analysis (Table 3.37) indicates a statistically non significant and irrelevant influence of the number of ANEs and the maximum SPL on the cortisol excretion. There is no significant interaction between ANE and SPL (p = 0.691).

Variable	β	p-value
Maximum SPL	-0.08620	0.291
Number of ANE	0.00489	0.834

Table 3.37: Mixed model regression calculation of nocturnal cortisol excretion rates and its statistical dependency on maximum SPL and number of ANE.

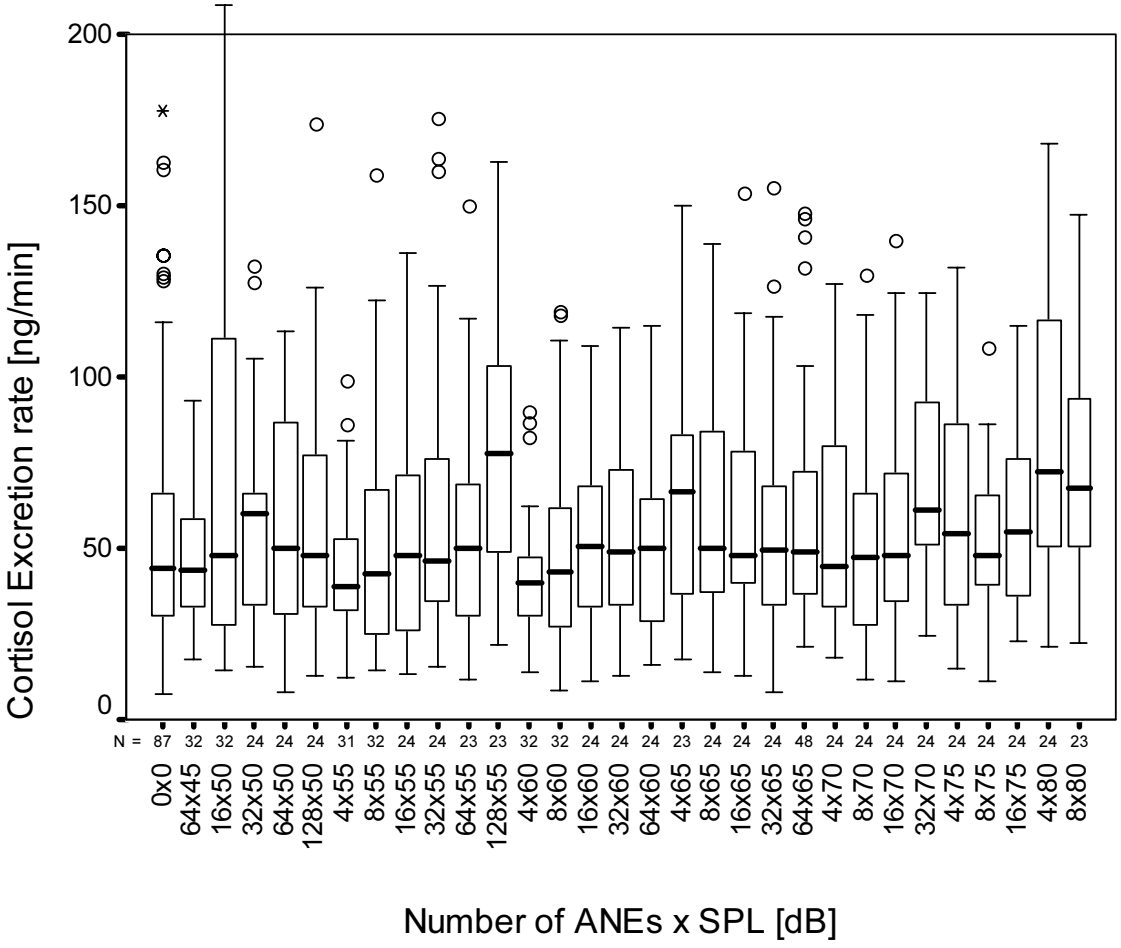

Figure 3.42: Box plot of the cortisol excretion rates in all night urine samples during laboratory studies (n = 88) depending on increasing numbers of aircraft noise events (ANE) and corresponding SPL during the nights. Laboratory studies comprise experimental groups only, with nights 2 – 11. N refers to the number of investigated nights.

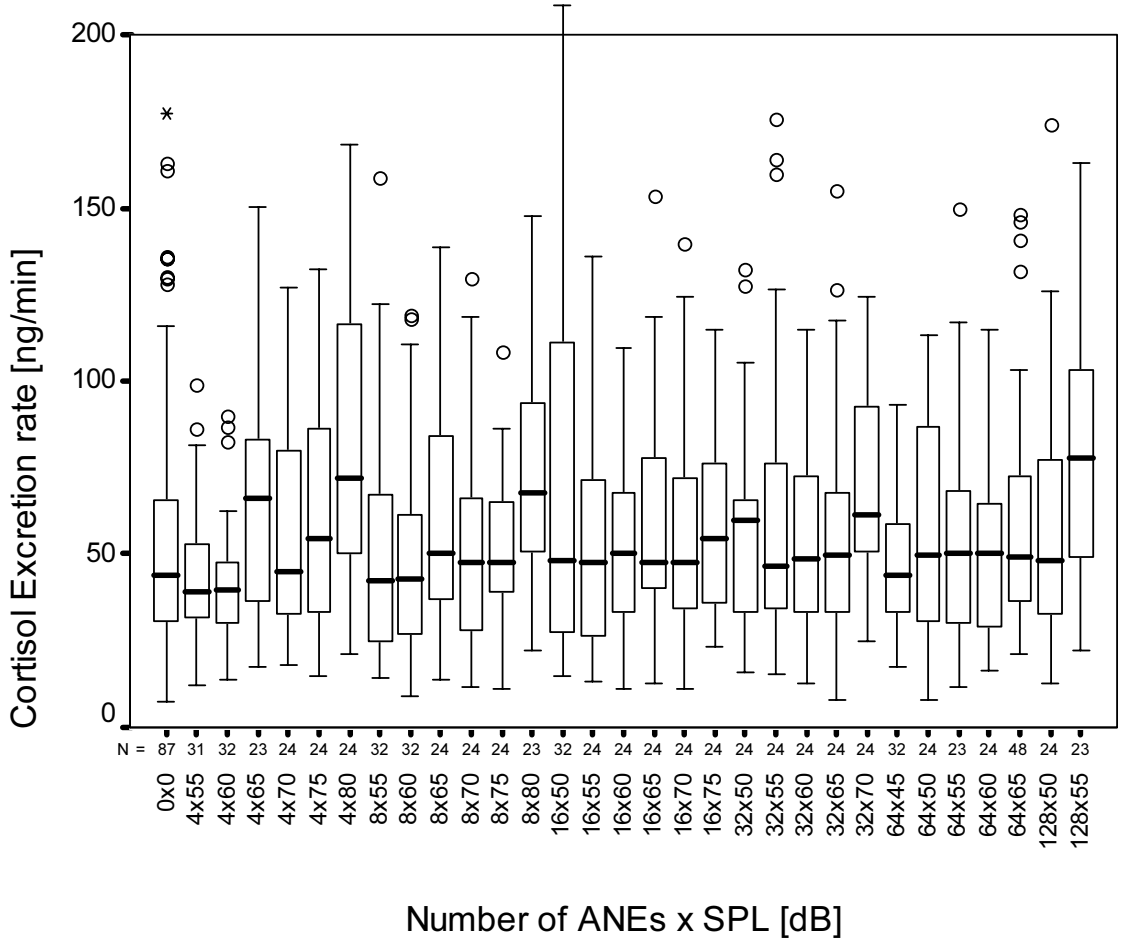

Figure 3.43: Box plot of the cortisol excretion rates in all night urine samples during laboratory studies (n = 88) depending on number of aircraft noise events (ANE) and corresponding increasing SPL during the nights. Laboratory studies comprise experimental groups only with nights 2 – 11. N refers to the number of investigated nights.

Table 3.38 illustrates in detail the statistical evaluation of cortisol excretion rates and their dependency on all interactions of maximum SPL and number of ANE per night. According to mixed model calculations cortisol excretion rates are only significantly higher than the baseline rate (56.5 ± 3.8 ng/min) during nights when 16 ANE at 50 dB (mean ± SE = 72.1 ± 4.7 ng/min, p = 0.002) were applied.

Maximum SPL LAS,max in dB	Number of Aircraft Noise Events per night					
	4	**8**	**16**	**32**	**64**	**128**
45					57.7±4.7 p=1.000	
50			**72.1±4.7** **p=0.002**	61.6±5.1 p=0.999	55.0±5.1 p=1.000	66.8±5.1 p=0.357
55	56.2±4.8 p=1.000	55.6±4.8 p=1.000	58.0±5.1 p=1.000	64.8±5.1 p=0.761	57.5±5.2 p=1.000	59.0±5.2 p=1.000
60	56.3±4.8 p=1.000	54.3±4.8 p=1.000	56.0±5.1 p=1.000	55.9±5.1 p=1.000	56.3±5.1 p=1.000	
65	60.0±5.2 p=1.000	57.5±5.1 p=1.000	61.9±5.1 p=0.997	61.3±5.1 p=1.000	59.4±4.3 p=1.000	
70	60.9±5.1 p=1.000	51.6±5.1 p=1.000	58.7±5.1 p=1.000	58.1±5.1 p=1.000		
75	64.1±5.1 p=0.858	52.4±5.1 p=1.000	55.0±5.1 p=1.000			
80	64.2±5.1 p=0.854	53.7±5.1 p=1.000				

Table 3.38: Estimated mean cortisol excretion rates (± SE) [ng/min] in all night urine samples during **experimental** laboratory studies (n = 88) depending on all combinations of maximum SPL and number of ANEs per night applied and their corresponding adjusted p-values with noise free (0x0) night # 2 (estimated mean ± SE = 56.5 ± 3.8 ng/min) serving as reference. Significance $p < 0.05$ in bold.

Figure 3.44 illustrates the cortisol excretion rates at night during field studies (48 subjects with times getting up 6:25 a.m. – 7:35 a.m.) in dependency on the number of traffic noise events per night. None of the exposure categories differs statistically significantly from the overall mean ($F = 0.41$ and $p = 0.798$). There is no dose-response relationship. A mixed model regression analysis (Table 3.39) indicates a statistically non significant and irrelevant influence of the number of traffic noise events per night and L_{eq} on the cortisol excretion. There is no significant interaction between L_{eq} and number of traffic noise events ($p = 0.455$).

Variable	β	p-value
Leq	0.29220	0.280
Number of Traffic Noise Events per Night	-0.00282	0.903

Table 3.39: Mixed model regression calculation of nocturnal cortisol excretion rates and its statistical dependency on Leq and number of traffic noise events per night.

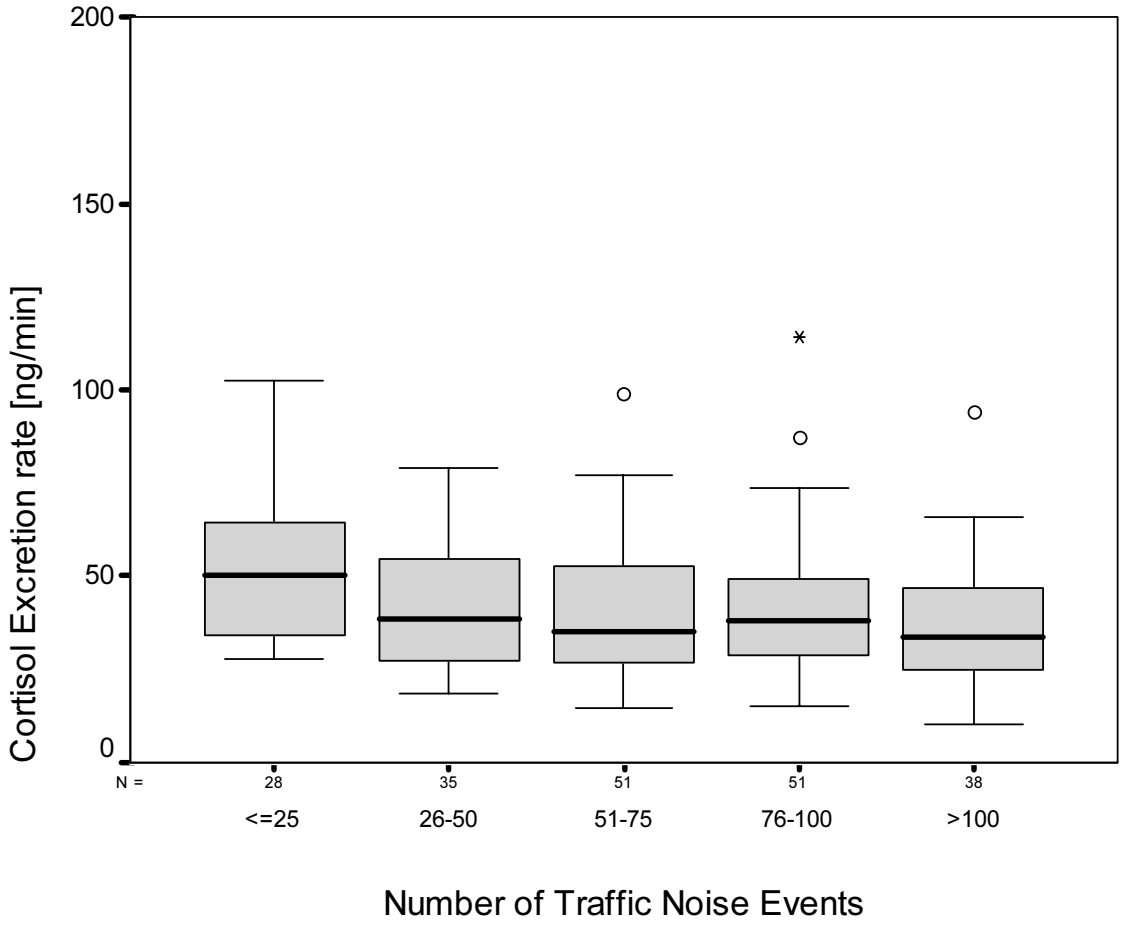

Figure 3.44: Box plot of the cortisol excretion rates in all night urine samples during field studies (n = 48) depending on number of traffic noise events during the nights. Field studies comprise all nights 2 – 9 and times of getting-up 6:25 a.m. – 7:35 a.m. N refers to the number of investigated nights.

Figure 3.45 and Figure 3.46 show in box plots the cortisol excretion rates in the laboratory studies comparing experimental and control groups, as well as in the field studies in dependency on the experimental night. In the control group, none of the exposure nights 1 – 13 differs statistically significantly from the overall mean (F-test: F = 1.17 and p = 0.317).

In the laboratory experimental group, the result of the F-test indicates that at least one of the experiment nights differs statistically significantly from the overall mean (F = 3.95 and p < 0.001). Post-hoc tests shown in Table 3.40 reveal, however that the cortisol excretion rates during all nights do not statistically significantly differ from that excretion rate during baseline night #2 (56.5 ± 3.8 ng/min). A mixed model univariable regression analysis indicates a statistically non significant and irrelevant increase of the cortisol excretion rate depending on the experimental night (p = 0.994; 0.001 ng/min per experimental night increase).

In the field group, the result of the F-test indicates that none of the exposure nights 1 – 9 differs statistically significantly from the overall mean (F = 1.89 and p = 0.065). A univariable regression analysis indicates a statistically non significant and irrelevant decrease of the cortisol excretion rate depending on the experimental night (p = 0.745; -0.11 ng/min per experimental night increase).

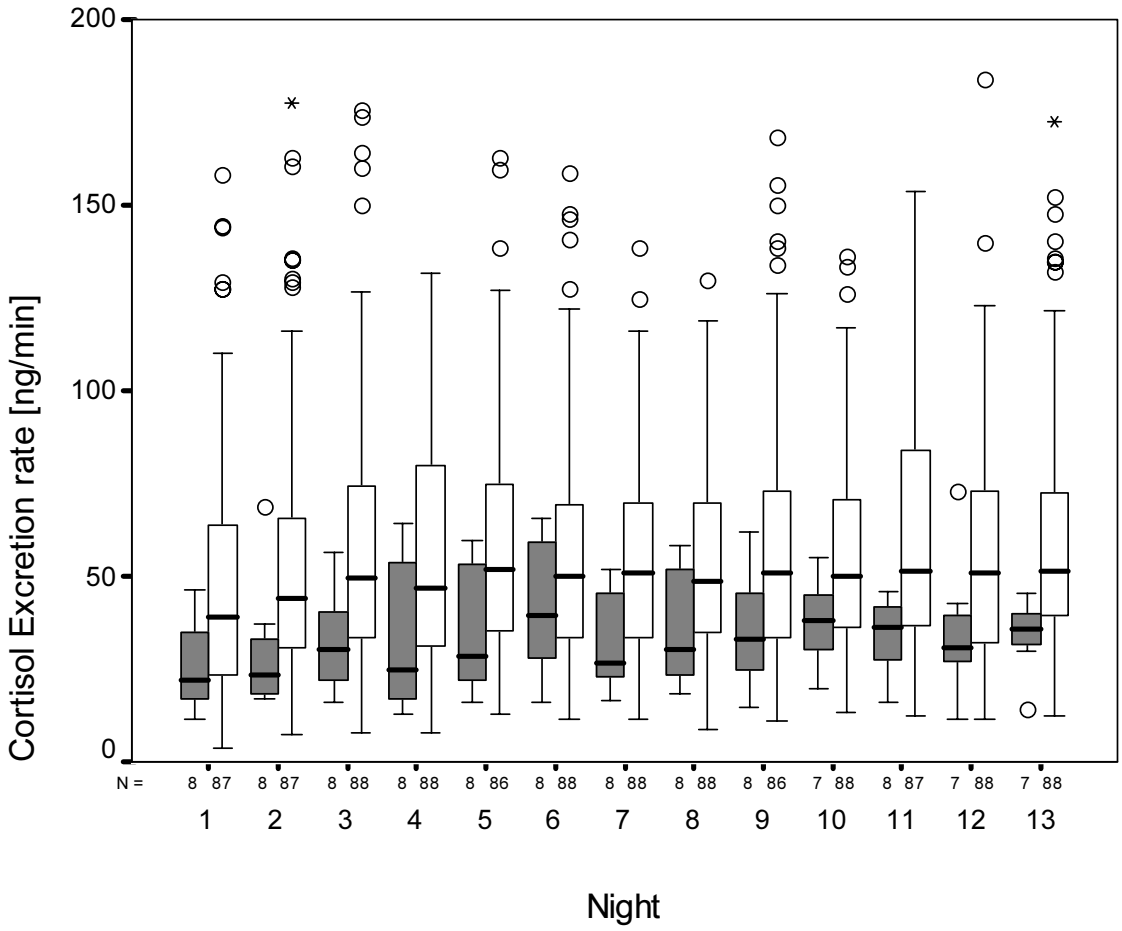

Figure 3.45: Box plot of the cortisol excretion rates in all night urine samples during both control group (grey boxes, 8 subjects) and experimental group (light boxes, 88 subjects) in the laboratory studies depending on the consecutive experimental nights. First nights were always Monday/Tuesday nights. N refers to the number of investigated nights.

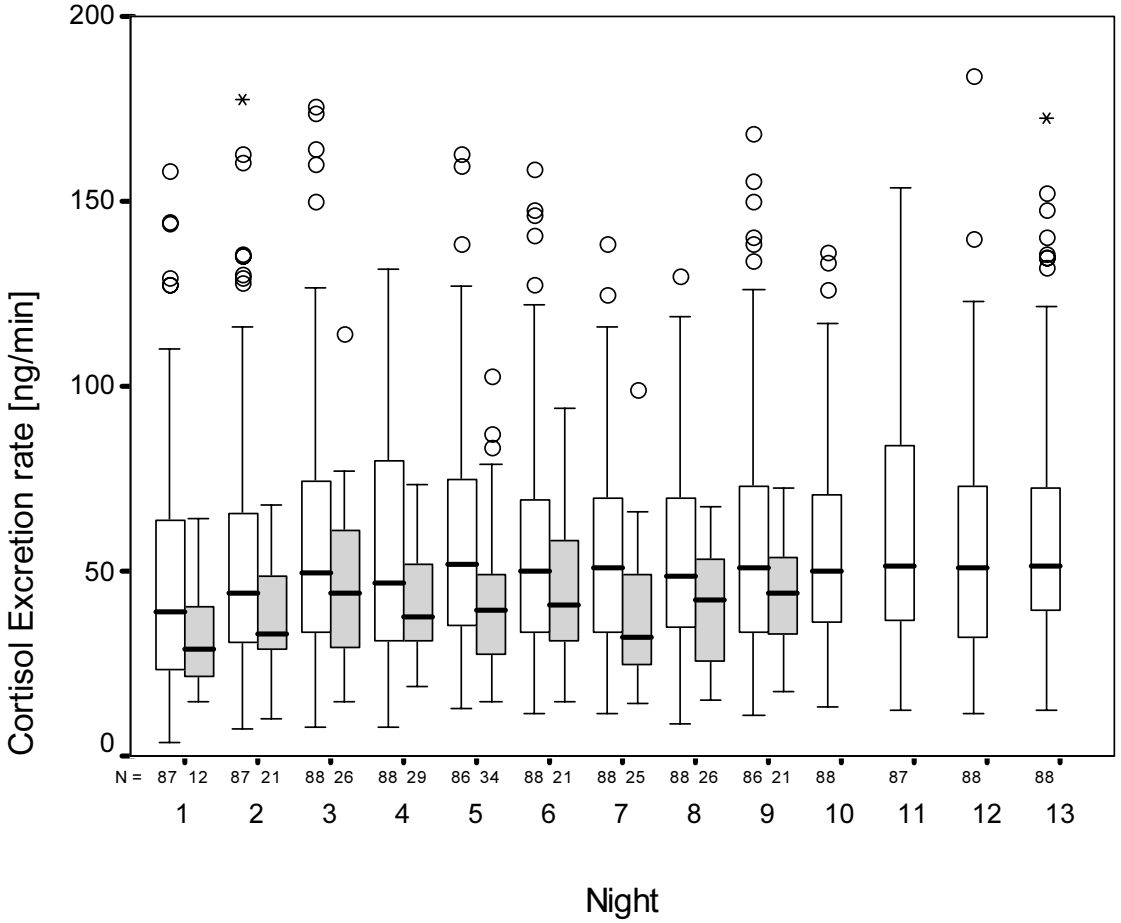

Figure 3.46: Box plot of the cortisol excretion rates in all night urine samples during both experimental group in laboratory studies (light boxes, 88 subjects) and in the field studies (grey boxes, 48 subjects, time of getting-up 6:25 a.m. – 7:35 a.m.) depending on the consecutive experimental nights. First nights were always Monday/Tuesday nights. N refers to the number of investigated nights.

Night	Estimated mean ± SE [ng/min]	Adjusted p-value
Night #1	50.5 ± 3.8	0.193
Night #2	56.5 ± 3.8	Reference
Night #3	63.5 ± 3.8	0.073
Night #4	55.9 ± 3.8	1.000
Night #5	61.0 ± 3.8	0.503
Night #6	57.2 ± 3.8	1.000
Night #7	55.3 ± 3.8	1.000
Night #8	54.2 ± 3.8	0.986
Night #9	61.3 ± 3.8	0.419
Night #10	57.4 ± 3.8	1.000
Night #11	63.1 ± 3.8	0.116
Night #12	56.7 ± 3.8	1.000
Night #13	60.8 ± 3.8	0.564

Table 3.40: Estimated mean cortisol excretion rates (± SE) in all night urine samples during experimental laboratory studies (n = 88) depending on experimental night and their corresponding adjusted p-values with night #2 serving as reference. Significance $p < 0.05$ in bold.

Figure 3.47 shows in box plots the nocturnal cortisol excretion rates in the laboratory and field studies excluding adaptation and recovery nights. Compared are the flux rates in dependency on the weekday. Neither in the laboratory experimental group of 88 subjects (F-test: $F = 2.08$ and $p = 0.053$) nor in the field group of 48 subjects who got-up between 6:25 a.m. and 7:35 a.m. (F-test: $F = 1.27$ and $p = 0.275$) any weekday differs statistically significantly from the overall mean cortisol excretion rate.

However, if all 64 subjects of the field studies, regardless of their time of getting-up are included in the statistical analysis (Figure 3.48) the F-test reveals that at least one weekday differs statistically significantly from the overall mean ($F = 6.46$ and $p < 0.001$). Table 3.41 shows in post-hoc tests that the cortisol excretion rate in the nights Saturday/Sunday is statistically

significantly higher (mean ± SE = 48.4 ± 2.4 ng/min) than the reference night Monday/Tuesday (mean ± SE = 39.6 ± 2.4 ng/min). This reflects the fact that the overall mean end of night time for the field subjects excluding the first night as adaptation is 6:35 a.m. ± 95 minutes (n =512 nights). On nights Friday/Saturday and Saturday/Sunday the appropriate mean end of night times are by 7:20 a.m. and by 7:48 a.m. ± 55 minutes respectively, when a mere 25% of subjects are awake by 7:00 a.m. In contrast, during weekday nights approximately ⅔ (n = 314 cases) of the subjects are awake before 7:00 a.m. (6:11 a.m. ± 34 minutes).

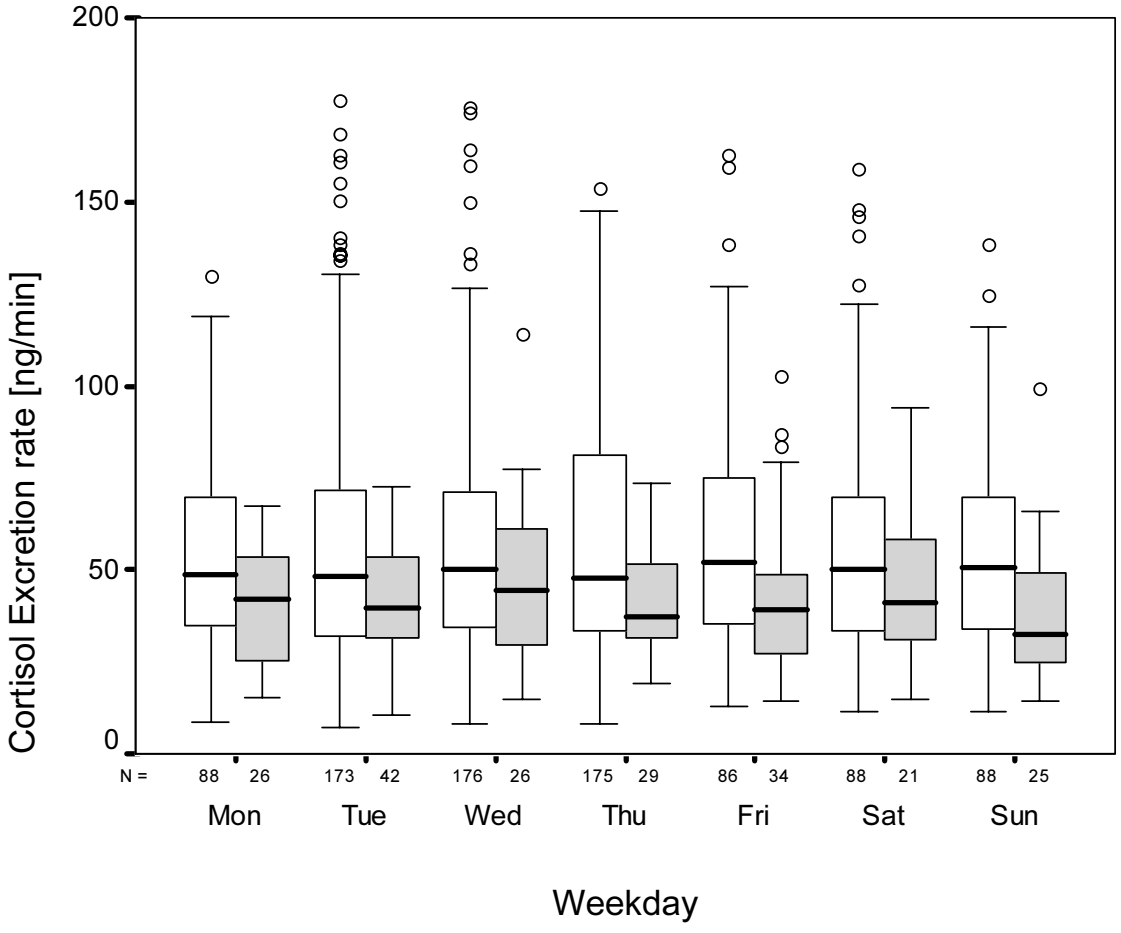

Figure 3.47: Box plot of the cortisol excretion rates in all night urine samples during both experimental laboratory studies (light boxes, nights 2 – 11, 88 subjects) and in the field studies (grey boxes, nights 2 – 9, time getting-up 6:25 a.m. – 7:35 a.m., 48 subjects) depending on the appropriate weekday night. First nights (excluded) were always Monday/Tuesday nights. N refers to the number of investigated nights.

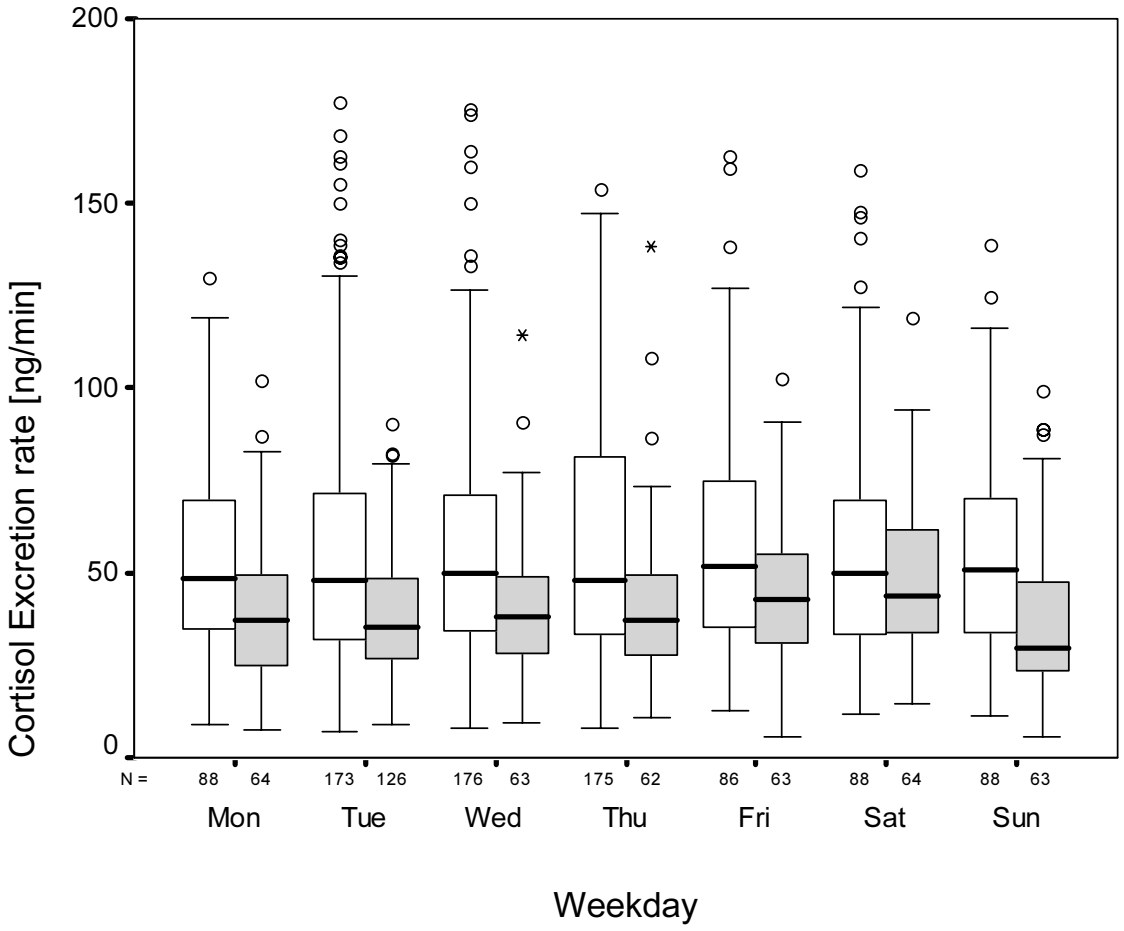

Figure 3.48: Box plot of the cortisol excretion rates in all night urine samples during both experimental laboratory studies (light boxes, nights 2 – 11, 88 subjects) and in the field studies (grey boxes, nights 2 – 9, regardless of time getting-up, 64 subjects) depending on the appropriate weekday night. First nights (excluded) were always Monday/Tuesday nights. N refers to the number of investigated nights.

Weekday Night	Estimated mean ± SE [ng/min]	Adjusted p-value
Monday/Tuesday	39.6 ± 2.4	Reference
Tuesday/Wednesday	38.7 ± 2.2	0.992
Wednesday/Thursday	41.6 ± 2.4	0.862
Thursday/Friday	41.7 ± 2.4	0.856
Friday/Saturday	45.2 ± 2.4	0.052
Saturday/Sunday	48.4 ± 2.4	**0.001**
Sunday/Monday	38.0 ± 2.4	0.940

Table 3.41: Estimated mean cortisol excretion rates (± SE) in all night urine samples during field studies (times getting-up before 6:00 a.m.until after 9:00 a.m., n = 64) depending on the weekday and their corresponding adjusted p-values with night #2 serving as reference. Significance $p < 0.05$ in bold.

Figure 3.49 illustrates in box plots the cortisol excretion rates at night in both the laboratory experimental and the field studies and their dependency from gender. F-tests show that there is no statistically different excretion rate between genders under laboratory conditions ($F = 0.56$ and $p = 0.456$, excretion rate in males mean ± SE = 55.5 ± 5.3 ng/min, and in females 60.7 ± 4.4 ng/min) and under field conditions ($F = 2.81$ and $p = 0.101$, excretion rate in males mean ± SE = 46.6 ± 3.7 ng/min, and in females 38.6 ± 3.0 ng/min).

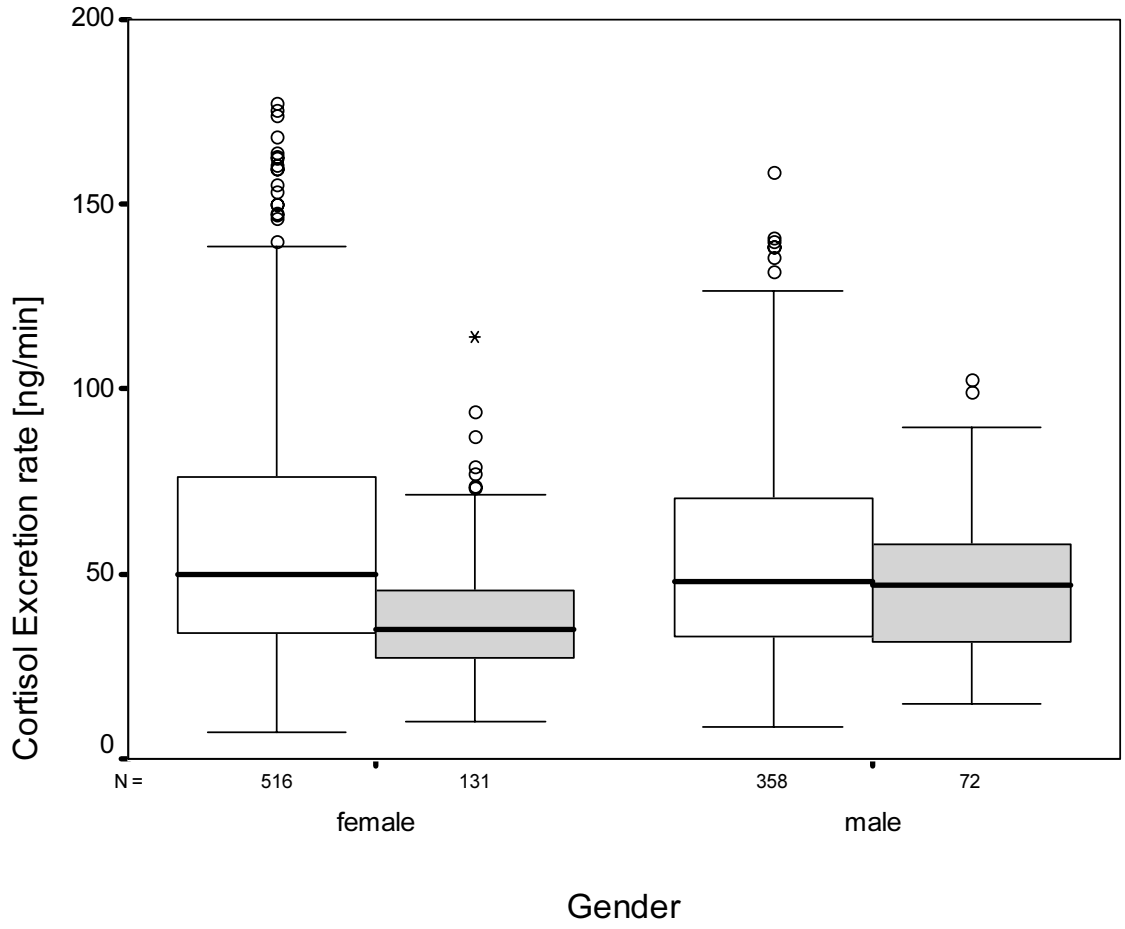

Figure 3.49: Box plot of the cortisol excretion rates in all night urine samples during both experimental laboratory studies (light boxes, nights 2 – 11, 88 subjects) and in the field studies (grey boxes, nights 2 – 9, time getting-up 6:25 a.m. – 7:35 a.m., 48 subjects) depending on gender. N refers to the number of investigated nights.

The closest fit to an equal age distribution among the participants (in laboratory studies: mean ± SD = 38 ± 13 years and in field studies: 37 ± 13 years) leads to six categories according to Table 3.31.

Figure 3.50 shows the box plots of nocturnal urinary cortisol excretion rates depending on the age class. Shown are the results of the experimental groups in the laboratory, nights 2 – 11, n = 88 (light boxes), and of the field group, nights 2 – 9 only excluding the adaptation night, and time getting-up 6:25 a.m. – 7:35 a.m., n = 48 (grey boxes).

The F-test applied to the data of the laboratory experimental group shows that there is neither a relevant nor a significant difference in any age class with respect to cortisol excretions (F = 0.55 and p = 0.736). A univariable regression analysis indicates a statistically non significant and irrelevant increase of the cortisol excretion rate depending on age (p = 0.302; 0.3 ng/min per year increase). The F-test applied to the data of the field group of 48 subjects states the same result (F = 0.46 and p = 0.803). A univariable regression analysis indicates a statistically non significant and irrelevant increase of the cortisol excretion rate depending on age (p = 0.127; 0.3 ng/min per year increase).

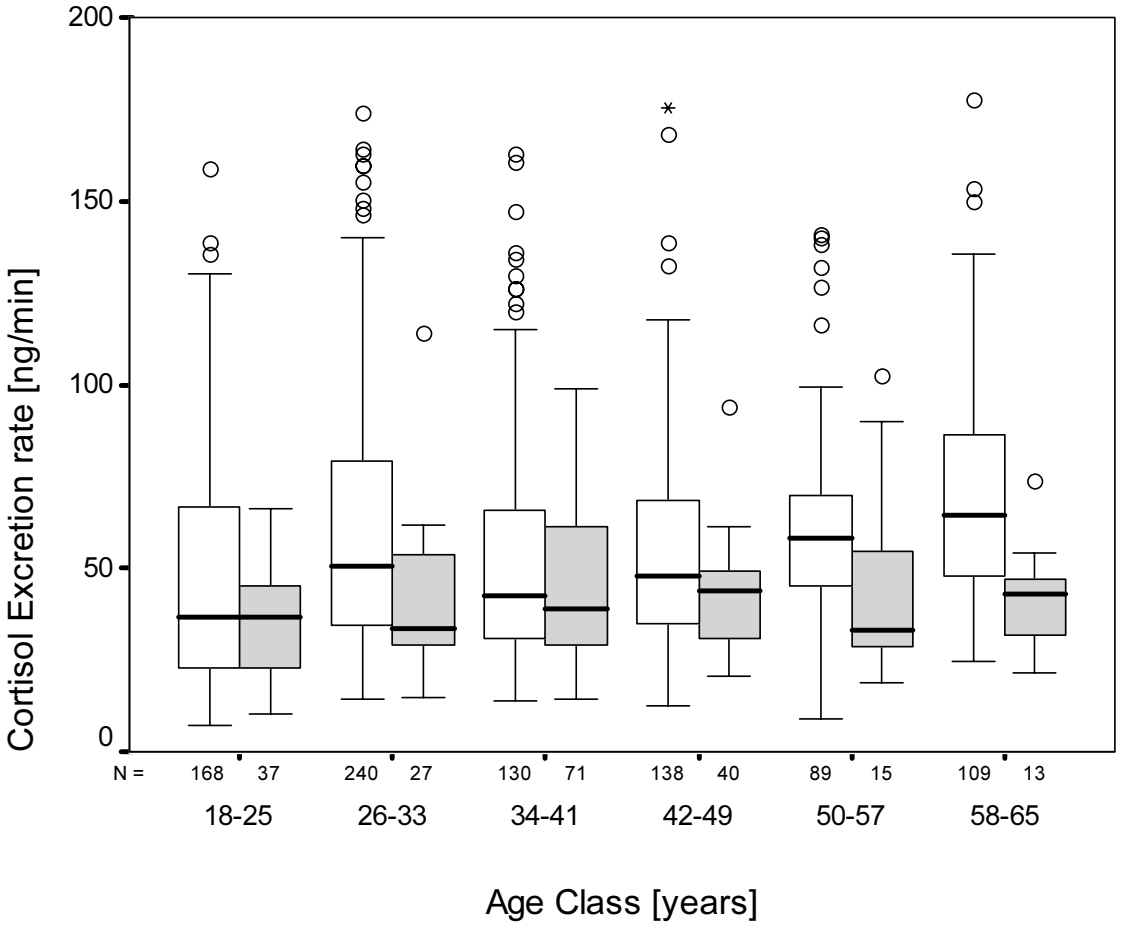

Figure 3.50: Box plot of the cortisol excretion rates in all night urine samples during both experimental laboratory studies (light boxes, nights 2 – 11, 88 subjects) and in the field studies (grey boxes, nights 2 – 9, time getting-up 6:25 a.m. – 7:35 a.m., 48 subjects) depending on the age class. N refers to the number of investigated nights.

Figure 3.51 and Figure 3.52 show in box plots the cortisol excretion rates depending on the subjects' noise sensitivity and their pre-annoyance level to aircraft noise. Shown are the results of the experimental groups in the laboratory nights 2 – 11 (n = 88). The results are given in light boxes. The results from the field studies, nights 2 – 9 and time to get-up 6:25 a.m. – 7:35 a.m. (n = 48) are indicated in grey boxes. The categories of noise sensitivity range from "very low" to "very high", respectively of the pre-annoyance level from "not annoyed" to "very annoyed". Their construction and psychological consideration with respect to nocturnal aircraft noise are reported in detail by Quehl [2004].

The F-test applied to the data of the laboratory experimental group of 88 subjects shows that there is no significant difference in cortisol excretions between the categories of noise sensitivity (F = 0.61 and p = 0.658). A univariable regression analysis indicates a statistically non significant and irrelevant decrease of the cortisol excretion rate depending on noise sensitivity (p = 0.546; -2.4 ng/min per 1 noise sensitivity level increase). The F-test applied to the data of the field group of 48 subjects states also that there is no relevant or significant difference in cortisol excretions between the noise sensitivity classes (F = 0.45 and p = 0.715). A univariable regression analysis indicates a statistically non significant and irrelevant decrease of the cortisol excretion rate depending on noise sensitivity (p = 0.507; -2.3 ng/min per 1 noise sensitivity level increase). The appropriate F-tests applied to the data regarding the pre-annoyance level of the subjects give similar results, namely for both the laboratory experimental and the field group there is no significant difference in cortisol excretions between the levels of pre-annoyance to aircraft noise (laboratory: F = 0.44 and p = 0.777; field: F = 1.18 and p = 0.334). The univariable regression analyses indicate statistically non significant and irrelevant decreases of the cortisol excretion rate depending on pre-annoyance level (in the laboratory p = 0.837; -0.7 ng/min per 1 pre-annoyance unit increase, and in the field p = 0.556; -1.4 ng/min per 1 pre-annoyance unit increase).

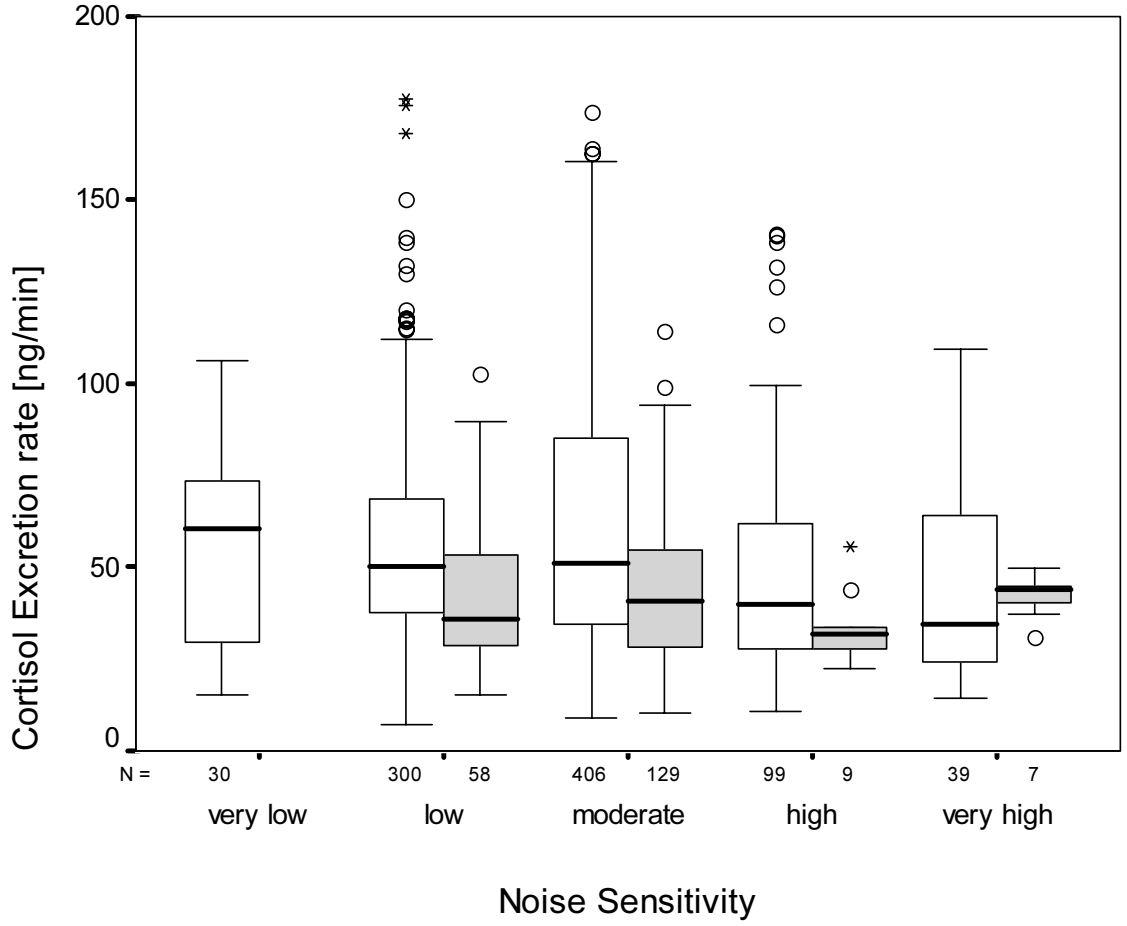

Figure 3.51: Box plot of the cortisol excretion rates in all night urine samples during both experimental laboratory studies (light boxes, nights 2 – 11, 88 subjects) and in the field studies (grey boxes, nights 2 – 9, time getting-up 6:25 a.m. – 7:35 a.m, 48 subjects) depending on the noise sensitivity of the subjects. N refers to the number of investigated nights.

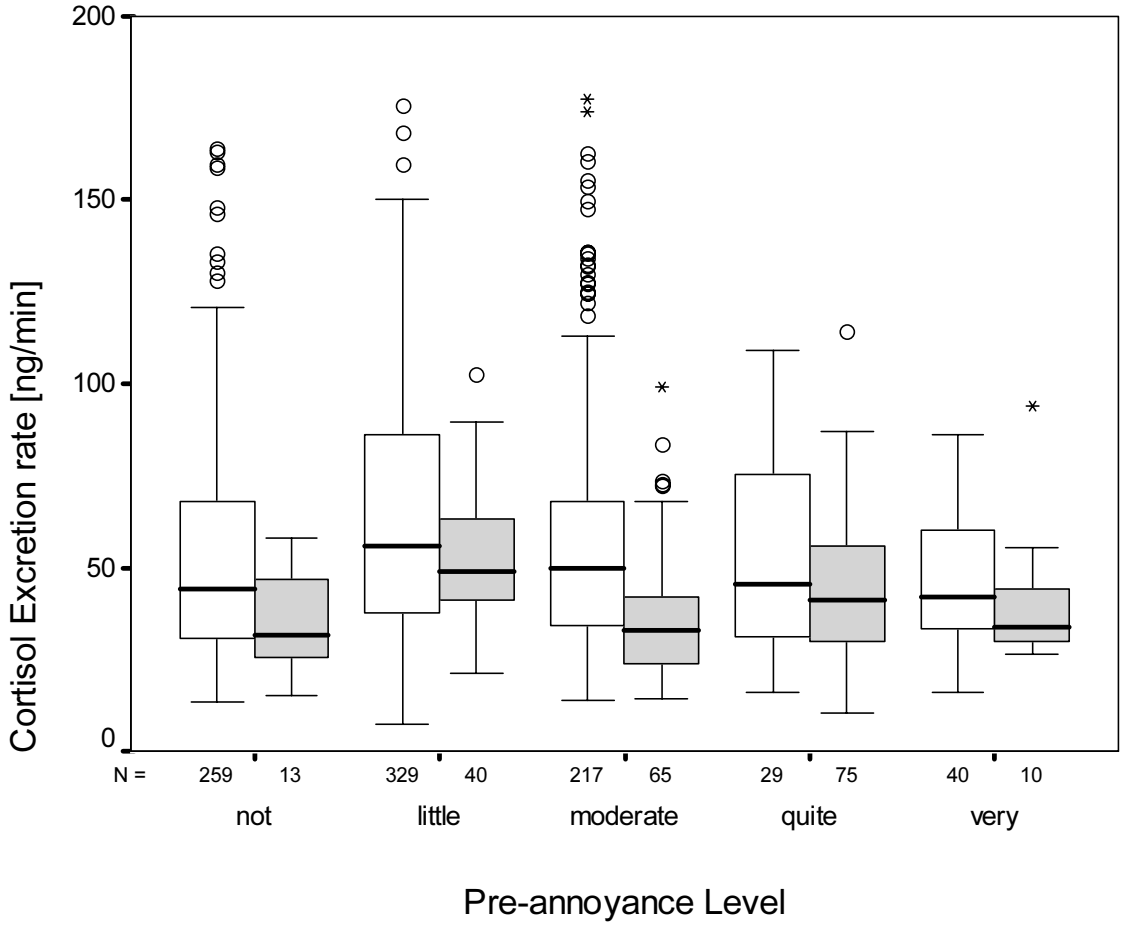

Figure 3.52: Box plot of the cortisol excretion rates in all night urine samples during both experimental laboratory studies (light boxes, nights 2 – 11, 88 subjects) and in the field studies (grey boxes, nights 2 – 9, time getting-up 6:25 a.m. – 7:35 a.m., 48 subjects) depending on the pre-annoyance level to aircraft noise of the subjects. N refers to the number of investigated nights.

Mixed model regression analyses for the laboratory experimental group (Table 3.42 and Table 3.43) that take several variables such as L_{eq}, number of ANEs per night and maximum SPL plus confounders like gender, age and noise sensitivity into account simultaneously, indicate statistically non significant and irrelevant influences of all of them on the cortisol excretion.

Table 3.44 shows the mixed model regression analysis for the appropriate variables from the field study. There is no significant or relevant influence on the cortisol flux rate observed.

Variable	β	p-value
Leq	-0.11390	0.284
Age	0.26540	0.315
Gender	-4.09410	0.558
Noise Sensitivity	-2.63150	0.511

Table 3.42: Mixed model regression calculation of nocturnal cortisol excretion rates in the experimental laboratory group and its statistical dependency on Leq and various confounders.

Variable	β	p-value
Number of ANEs	0.00481	0.837
Maximum SPL	-0.08832	0.279
Age	0.26650	0.313
Gender	-4.09970	0.557
Noise Sensitivity	-2.63470	0.511

Table 3.43: Mixed model regression calculation of nocturnal cortisol excretion rates in the experimental laboratory group and its statistical dependency on number of ANEs and max. SPL and various confounders.

Variable	β	p-value
Leq	0.24890	0.358
Number of Traffic Noise Events	0.00151	0.948
Age	0.296200	0.145
Gender	9.31140	0.060
Noise Sensitivity	-3.69670	0.289

Table 3.44: Mixed model regression calculation of nocturnal cortisol excretion rates in the field group and its statistical dependency on Leq and various confounders.

Summarized in Table 3.45, the results of all aircraft noise relevant categories for stress hormone excretions that were statistically tested are shown. Only noradrenaline and cortisol data are given. Adrenaline is excluded in this table, since its excretion rates were too low for regular detection and subsequent statistical analysis.

	Noradrenaline		**Cortisol**	
	Laboratory p-value	**Field p-value**	**Laboratory p-value**	**Field p-value**
Noise (L_{eq} class)	0.895↑	0.640↓	0.297↓	0.280↑
Maximum SPL	0.612↑	n/a	0.291↓	n/a
Number ANE or Traffic Noise Events/night	0.162↓	0.839↓	0.834↑	0.903↓
Max. SPL*ANE	0.991	n/a	0.691	n/a
Leq*Traffic Noise Events	n/a	0.723		0.455
Experimental night	0.119↓	0.437↓	0.994↑	0.745↓
Weekday	0.535↓	0.485↓	0.053↑	0.275↑
Gender	0.837↑	0.182↓	0.456↓	0.101↑
Age	0.368↑	**0.045**↑	0.302↑	0.127↑
Noise sensitivity	0.402↓	0.762↓	0.546↓	0.507↓
Pre-annoyance	0.690↓	0.980↑	0.837↓	0.556↓
20 identical subjects in Lab. and Field	0.774↑		0.238↓	
Laboratory vs. Field	0.833↑		**<0.001**↓	

Table 3.45: p-values of mixed model regression analyses and F-tests applied to noradrenaline and cortisol excretion rates vs. all study relevant categories. Significance ($p < 0.05$) is highlighted in bold. Arrow directions indicate increase (↑) or decrease (↓) **regardless of magnitude of effects**.

4 Discussion

The conventional concepts of stress, stressor action and stress coping being fundamental structures of life and essential for survival, describe its influence on important stress hormones, such as e.g. catecholamines and cortisol. Subsequently, these hormone releases result in sub cellular or cellular variations of electrolyte concentrations which may be detected in urine excretions, finally. However, catecholamine or cortisol secretions do not occur exclusively due to stress specific reactions. Cortisol, for instance, is involved in a multitude of bodily functions and regulations. Therefore, stressors and stress reactions are non specific. Among many others, noise is a well known stressor and thus may cause those hormone changes described. Some authors argue that nocturnal aircraft noise can lead to an increased excretion of these hormones which can be detected in the urine collected during the stressful nights [Maschke et al. 1995, Harder et al. 1999].

4.1 Electrolytes

With respect to electrolyte imbalances, in our studies we find no strong connection of electrolyte fluxes at night with nocturnal aircraft noise. Significant connections are seen in potassium and calcium values in the laboratory but not the field, while sodium and magnesium excretion rates are not related in any way to noise events. Quite striking, however, is the difference between laboratory and field studies regardless of any noise pattern applied, and the importance of the experimental night in the laboratory. Excretions of urinary electrolytes such as sodium, potassium, calcium, and magnesium are highly dependent on dietary intake with normal ranges in adults for sodium at 19-200 µmol/min, for potassium at 17-87 µmol/min, for calcium at 1.7-5.2 µmol/min, and for magnesium at 1.7-5.9 µmol/min, calculated from rates per day according to standards listed by Tietz (1995)

and Sitzmann (1986). Mean values obtained in our studies did not exceed these ranges. What we measure in singular urine samples over night reflects mostly the intake of electrolytes during the previous evening. Dinner was served upon arrival of our subjects at the laboratory by 7 p.m., and then they were free to drink and eat snacks until going to bed, with the mentioned restrictions like caffeine etc. Within the laboratory environment and without any major time consuming tasks during 4 hours, except for the required performance tests by 9 p.m., and in company with all other study members, consumption of juices and mineral water (rich in electrolytes) was high. Sometimes potato chips, salted peanuts or similar food was available. Here seems to be the source for the difference of electrolyte excretions, and the variation on the different experimental days. At their homes, people most likely did not eat and drink regularly as much that late, at least no food or beverages that contained such high electrolyte concentrations. And this is reflected with the time course of the laboratory experiment, i.e. getting acquainted to the lab situation and the food and drinks. Here is also the main reason for the difference of laboratory and field excretion rates for sodium, magnesium, and calcium that is much lower in the field.

Unless there is a very strict regime of well balanced and controlled food and beverages intake, electrolyte concentrations in urine are of no further help to shed light on stress reactions due to noise impact. Additionally, even better results might be derived from the investigation of intracellular electrolyte shifts with noise exposure. These requirements, however, were impossible to meet during our studies here. Ising et al. [1999a, 1999b] report on several studies both in animals (rats and dogs) and humans. Stress reactions were provoked by acute noise events causing magnesium loss and an increase in intracellular calcium, beside profound noradrenaline and cortisol excretions. Noise events however, were at extremely high SPLs (up to more than 100 dB), and never during resting times. Magnesium depleted rats exhibited high urinary noradrenaline concentrations with high noise levels. The authors themselves also state that in long-term exposures animals not

always showed chronic stress hormone increases, even if exposed life long, and that during sleep, noise levels leading to stress reactions are much lower.

Harder et al. [1999] report on erythrocyte magnesium shifts in 16 subjects who had undergone 6 weeks of nocturnal aircraft noise (maximum SPL = 65 dB at 32 ANE per night). However, only one subject developed a negative magnesium balance, whereas 5 out of 16 were low all the time. There are no indications that the investigated subjects received balanced diets. From these results it may be repeated that investigations on possibly subtle electrolyte shifts with respect to stress are useful under extremely well controlled conditions only, including diet balances. In our studies such electrolyte shifts could not be observed.

4.2 Adrenaline

Conflicting statements exist regarding the detection of increased adrenaline excretion in human subjects after acute traffic noise exposures. For instance, Maschke [1992] and Maschke et al. [1995] found an increase of catecholamines, whereas other authors [Carter et al. 1994] did not detect any changes. Based on the data shown in our studies, it can be deduced that nocturnal aircraft noise events do not cause elevated adrenaline excretions insofar that a noteworthy amount can be detected in the urine. Adrenaline was detectable only in roughly a quarter of nocturnal urine samples at all, regardless of any noise impact. Even during nights with very high noise exposure (maximum SPL and/or ANEs per night), a distinct increase of adrenaline excretion within the night urine is not detectable from our data. Statistically, a correlation between the rate of adrenaline excretion and Leq or maximum SPL and/or ANE per night cannot be concluded.

Additionally, when adrenaline is detectable in urine, maximum adrenaline excretions from noisy nights (> 3 ng/min) exceed those of quiet nights in merely 2% of the cases. All these values are much lower compared to those seen in non-stressful environment like sitting in the laboratory having dinner and waiting to go to bed (evening flux rates). It can be concluded that adrenaline analysis from all night urine samples is possibly a too insensitive parameter. Should aircraft noise events only lead to momentary elevations of the adrenaline level in the blood, it could be speculated that all these episodes together are not sufficiently long enough in the progression of an entire night length of approximately 480 minutes, in order to achieve a measurable concentration in the total volume of urine. This might be due to the short biological half life of adrenaline. However, adrenaline is almost always detectable in the urine samples that were collected during the evenings in the AMSAN laboratory from 7 p.m. till 11 p.m., when the study subjects were still active and not yet in bed. This indicates sympathetic-adrenergic activity of the subjects at these times, and also the sufficient measurement accuracy of this method. Our results are in accordance with those of Osada et al. [1969] and Carter at al. [1994], who could not detect increased adrenaline secretion due to noise or aircraft noise. In a lab experiment, Maschke [1992] detected an increase of adrenaline excretion corresponding to the maximum SPL and the number of events. However, the collective (8 subjects, 10 nights) is very small for profound statistical statements and conclusions. Possibly, the conditions at home cannot be directly compared to those in a laboratory, since the examined persons may exhibit a higher activity there. This could be supported by our results comparing tables 2 and 3 that show higher percentages of adrenaline detection in night urines of field subjects in spite of lower noise loads.

4.3 Noradrenaline

Noradrenaline can be easily detected in nocturnal urine samples, in contrast to adrenaline. Findings from the control group without any exposure to air-

craft noise show that nights do not differ from each other. The study subjects who were exposed to aircraft noise also exhibit similar excretion rates in the noise-free second lab night (baseline night). However, the average flux rates during aircraft noise exposure are statistically significantly lower than those of the noise-free-nights (Fig. 3.32 and Table 3.25). Possibly, night #2 that served as baseline night was not yet the final settling to be completely accustomed to the new environment in our laboratory at night. A similar dependency of noradrenaline flux rates and the investigation night in the field could not be shown. Basner et al. [2005] observed a pronounced first night effect in all sleep variables within our study. However, there was no statistically significant difference between night #2 and all following nights within the control groups. This indicates that one night of adaptation was sufficient.

The same pattern is visible when noradrenaline excretion rates and Leq classes are investigated. With noise free nights always at the beginning of the study, all later noisy nights pooled to Leq classes, show significantly lower noradrenaline excretion rates. There is no difference between values obtained under laboratory or field conditions. Especially, those 20 subjects who took part in both laboratory and field studies do not reveal different excretion rates. We cannot support from our data that long-term exposure to night air traffic noise as investigated in our study, leads to higher excretion rates in all night urines. Noradrenaline excretion rates do not depend on pre-annoyance to aircraft noise, noise sensitivity, age or gender. There might be a tendency towards higher excretion rates with age.

From our results the normal range of noradrenaline excretion for adults at 15-80 µg/d [Tietz 1995] is never exceeded. Any stress induced reaction visible due to increased hormone excretion is not detectable.

In conclusion, for the results concerning catecholamines it can be determined that the excretion of noradrenaline in the nocturnal urine collections does not change due to aircraft noise events neither under laboratory nor

under field conditions. Here one has to keep in mind that our field studies were also on people having lived for a long time in areas exposed to air traffic noise. From our findings we conclude that the attempt to measure excretions of adrenaline in all night urine samples, as has been done in the past repeatedly, is inappropriate, since nocturnal aircraft noise does not raise its concentrations to a detectable – and relevant - level there. Desirable measurements of catecholamine changes as an activation of the sympathetic nervous system, exactly when noise events are applied (event-correlated), are extremely difficult to perform leading to invasive methods that jeopardize sleep parameters or impair other important measurements (e.g., the recording of the EEG, EKG, finger pulse etc.), and consequently becoming an additional stressor. Here we refer to results from other non-invasive methods like plethysmography and heart rate that had been recorded within our studies and that will be reported elsewhere.

4.4 Cortisol

Free cortisol as a prominent stress parameter under aircraft noise exposure was studied by various authors [Evans et al. 1995, Hygge et al. 1998, Kastka et al. 1999, Maschke et al. 1995, Harder et al. 1999]. In general, cortisol concentrations were determined from urine samples collected all night. Results were ambiguous with increasing, unchanged, and even falling excretion rates during noise exposures.

Regrettably, the analysis lab changed the method of free cortisol determination without consultation for one study phase with 32 subjects (8 controls, 24 experimental). This resulted in completely different standard curves for RIA and EIA methods which could not be transformed. The repeated determination of free cortisol from deep frozen material kept in storage months later, using the proper original RIA method showed that results from such urine samples were not acceptable and usable showing lower

and higher values at random. Therefore, data from the EIA group (STRAIN II) were excluded and not used for further analyses.

With respect to the methods applied for analyzing free cortisol, most clinical laboratories favoured the RIA method, originally and substitute it more and more by the EIA or non-radioactive methods during recent years which is not least due to the fact of avoiding the handling of radioactive material. However, normal ranges and recovery rates are different and depending on chosen methods. Maschke [2002a] proposed the application of HPLC to overcome disadvantages of immuno assay techniques (e.g. cross reactions of metabolites) and to determine not just free cortisol but also metabolites. The biological active compound and relevant hormone, however is free cortisol only. The concentrations of corticoid metabolites deriving from various sources are difficult to attribute to cortisol degradation, unless isotope labelled beforehand. They might be helpful if free cortisol could not be determined directly. Formerly, when free cortisol determination in urine was not yet available, for screening purpose the concentrations of metanephrines and vanillylmandelic acid (VMA) were the chosen methods instead. Modern immuno assays are developed to minimize cross reactions with relevant metabolites, and usually are verified by another method, e.g. HPLC or mass spectroscopy, methods which are often much too extensive and expensive. Therefore, EIA and RIA are the current methods chosen for the determination of free cortisol concentrations in clinical routine.

In our studies presented here, nocturnal cortisol excretions show only significant increases at one occasion: a singular ANE per night (16 ANE per night at 50 dB, table 3.31). There is no statistically significant or relevant connection detectable with L_{eq} classes or maximum SPL. No threshold is indicated of which cortisol excretion might be significantly increased after acute noise stress. No trend is detectable in the field studies either where, in total, excretion rates are significantly lower than in the laboratory.

The pronounced circadian rhythm of the cortisol secretion has to be considered. This rhythm is characterized by inter-individual differences regarding amplitude and phase. However, it is very stable intra-individually. Since the circadian rhythm could not be explicitly measured, the following aspects are especially important for the interpretation of the cortisol data: 1) the assurance of a rather rigid sleep scheme and furthermore, 2) the designation of a reference parameter (second, noise-free night as control night) solely from values of those persons, who were later exposed to aircraft noise, thus enabling an intra-individual comparison. These aspects could be met in our laboratory studies and partly in our field studies. Yet another aspect should be taken into account, namely that cortisol secretion at night depends on sleep stage [Born 2000, Marshall 2002]. Steiger [2002] in his review states, however, that most studies agree that the circadian pattern of cortisol is relatively independent from sleep and environmental influences. This supports Redwine et al. [2000] who show that partial sleep deprivation for even several hours affects interleukin-6 and growth hormone patterns, whereas the hormones cortisol and melatonin remain unchanged. Voderholzer et al. [2004] deprived depressed patients of sleep for an entire night and found transient and favourable elevated cortisol levels during the deprivation period. This was done, however, for therapeutic effects and improvement of depression. For methodological and practical reasons, we did not take blood or saliva samples, or several urine samples per night to study this particular effect of sleep stage and cortisol flux.

In the field studies subjects exhibit no particular cortisol response to nocturnal air traffic noise. However, in the field Leq values above 45 dB did not occur. Quite obvious is the influence of sleeping length which is *per se* close to collection period of urines. During weekend nights when there was considerably lower air traffic than during the week, cortisol excretion in urine samples was highest. Again the endogenous cortisol secretion is the reason. Whereas approximately ⅔ of the subjects were awake by 7 am during weekday mornings, barely 25% were awake on Sunday mornings. The

subjects got up on average more than one hour later than normally. Therefore, for comparison to laboratory conditions, nights were not considered when subjects slept in after 7:35 a.m., or got up before 6:25 a.m., because lower cortisol excretion rates in the field may also result from earlier getting up than in the laboratory. It is known that e.g. laboratory studies show more disturbances and greater awakening reactions than field studies, in general [Pearsons et al. 1995, Finegold 1993, Basner et al. 2004]. Maschke et al. [2002] report on findings about cortisol response depending on the weekday, while Persson Waye [2004] could not verify such a view. No effect on cortisol flux depending on low-frequency noise exposure during nights was seen. If adjusted to the similar collection periods, we do not find any influence of the weekday on cortisol excretion.

Maschke et al. [1995] report on noise-annoyed women, whose noradrenaline and cortisol secretions are elevated due to the level of annoyance. Adrenaline secretion does not exhibit a change. In our study there is no correlation of pre-annoyance or noise sensitivity resulting in detectable secretion of catecholamines or cortisol in the sense of more or less annoyed or sensitive groups. We cannot support any effect of age, gender, air craft noise annoyance level or general noise sensitivity on the excretion rate of cortisol.

The published results regarding the cortisol secretion during aircraft noise exposure are very contradictory. Kastka [1999] and Evans [1995] could not prove any connection. The group around Evans later did find a significant relation [Harder et al. 1998]. Harder et al. [1999] also did not observe a significant increase in the cortisol excretion in the group average during a 40 days exposure of the study subjects. Aside from the unchanged values, increasing and declining temporal progressions could be observed in some of the study subjects. Classification of these subjects into several sub-groups and in connection to an extrapolation of hypothesized cortisol excretions during the nights seems very problematic. Spreng [2002] proposed a mathematical model of cortisol excretion and deduced the tolerable noc-

turnal aircraft noise. However, we could not verify in our studies the assumption of increasing urinary cortisol flux rates depending on the aircraft noise applied.

In conclusion, apart from the method chosen, the amount of free cortisol from urine samples collected during all night is dependant on the exact collection periods. Otherwise the pronounced circadian rhythm of cortisol excretion may cause a problem interpreting any stress induced effects. In the early morning hours when cortisol excretion usually peaks endogenously, additional stress induced cortisol secretion may be masked. Stress reactions at night might be masked by mere dilution by increasing urine volumes. Therefore, noise effect investigators who had originally favoured all night urine collections turned to more than a single collection period, i.e. accepting a voluntary interruption of natural sleep patterns [Ising et al. 2001]. Problems are deriving here from anticipation of such awakenings and possible prolonged sleep onset after enforced awakening causing a different kind of stress, finally [Born et al. 1999]. Cortisol findings from urine samples bear always the risk of underestimation of short term stress factors. Here are the limitations of the present study that involved a multitude of aspects of nocturnal aircraft noise effects on humans, and where the prime focus has been put onto the influences on sleep and its changes.

Under the conditions investigated in the laboratory and the field, the findings of the present study indicate a very low influence of nocturnal aircraft noise on the chosen parameters, if any. The most important findings, i.e. the results of catecholamines and cortisol excretion rates, do not support the hypothesis that the applied or measured aircraft noise leads to augmented stress reactions detectable in nocturnal excretion rates.

5 Literature

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