Noise in Preschools and its Psychological and Cardiovascular Effect on Preschool Teachers

Sonja Brachtl[1], Michael Trimmel[2]

[1]Department for Continuing Education Research and Educational Technologies, University for Continuing Education Krems, Krems, Austria,
[2]Centre for Public Health, Institute of Environmental Health, Medical University of Vienna, Vienna, Austria

Abstract

Purpose: Noise exposure in preschools is cited as one of the main stresses by preschool teachers in surveys worldwide. Hearing-related symptoms as well as physiological stress reactions are often mentioned in this context. Therefore, the aim of the study was to investigate whether the noise has an impact on the cardiovascular activity of the preschool teachers. **Methods:** The study took place in nine private preschools in Vienna. In the classrooms of 23 preschool teachers stationary noise recordings were conducted and the participants were equipped with 24-hour electrocardiograms (ECGs). Questionnaires on noise-related stress, well-being, stress perception, burnout risk, noise annoyance, and noise sensitivity were provided. Data were described descriptively and correlations and one-way analyses of variance (ANOVAs) with repeated measures were performed. **Results:** The average sound pressure level in the classrooms during the first four hours was L_{Aeq} 74.7 dB(A) (standard deviation [SD] = 1.74). A significant correlation between heart rate and sound pressure level ($L_{Aeq,4\,h}$) was found, $r = 0.40$, $P = 0.04$ (one-tailed). Noise sensitivity and noise annoyance showed no effect. With increasing sound level classes [≤65 dB (A), 66–75 dB(A), 76–85 dB(A)], the heart rate increased significantly, and the heart rate variability decreased significantly. It was also found that tolerating noise becomes more difficult with increasing length of employment and increasing age. **Conclusion:** The noise level in classrooms showed an impact on the cardiovascular activity of preschool teachers, which can be considered as an indicator of stress. Measures to reduce noise in preschools are recommended.

Keywords: Noise, Preschools, Preschool teachers, Heart rate, Heart rate variability

Key Messages: Noise level in preschools is associated with increasing heart rate and lower heart rate variability and becomes more difficult to tolerate with increasing duration of employment and age.

Introduction

Noise exposure in preschools and its stress on preschool teachers has been investigated for many years around the world.[1-11] Stationary noise measurements in preschool classes reaches in average levels from L_{eq} 70 dB(A), up to more than L_{eq} 80 dB(A) and personal recordings with noise dosimeters can reach even higher levels above L_{eq} 85 dB (A).[5-8]

Reasons for the generation of noise in preschool classes can be found in the sounds that children produce, in particularly from the activities they are engaged in.[1,3,8,9] Highest noise levels have been found during group work and movement,[3] play,[1] as well as music time and dropping heavy play equipment.[8] Sound levels have also been found to increase with the number of children in a group,[2],[3],[5],[8] which can be attributed to the Lombard effect and of the resulting behavioral effects.[5],[11] Another reason was found in the age of the children,[3],[9] whereby the highest noise levels often occur with younger children due to crying and screaming.[9] Further reasons can be found in the construction of the buildings,[4] with higher noise levels being found in

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Address for correspondence: Sonja Brachtl, Department for Continuing Education Research and Educational Technologies, University for Continuing Education Krems, Dr.-Karl-Dorrek-Straße 30, 3500 Krems, Austria.
E-mail: sonja.brachtl@donau-uni.ac.at

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preschools that follow an open plan concept compared to enclosed classrooms.[10] The lack of soundproofing measures is another reason for high noise levels in educational institutions due to long reverberation times in the premises; studies have shown a decrease in sound levels after the installation of sound absorbers[12],[13] and further acoustical treatments such as changing floor mats and adding damping cushions under chairs.[14]

With regard to the risk of noise-induced hearing loss, the Directive 2003/10/EC sets exposure limit values depending on the equivalent noise level for an 8-hour working day, $L_{EX,8\,h} = 80$ dBA for the first (lower) action level, $L_{EX,8\,h} = 85$ dBA for the second (upper) action level and $L_{EX,8\,h} = 87$ dBA as the maximum exposure limit.[15] The World Health Organization (2018) recommends different thresholds for road traffic noise, railway noise, aircraft noise, wind turbine noise, and leisure noise.[16] The World Health Organization (WHO) Guidelines for Community Noise recommends a background sound level during teaching sessions in schools and preschools of 35 dB L_{Aeq} in order to hear and understand spoken messages.[17]

Acute noise effects can already occur at lower environmental sound levels, when certain activities such as concentration, relaxation, or sleep are disturbed[18-20] and with increasing complexity of work activities.[21] In education, the complexity lies in the teaching process and the interference from noise increases with larger groups, while different mother tongues and social skills must also be considered.[21] Furthermore, background noise has also negative effects on attention and learning in general[22-24] and in particular on speech perception for children combined with an increased risk of developing voice problems for preschool teachers.[1],[7],[9],[21] The ÖAL Guideline No. 6/18[25] points out that clear speech intelligibility is no longer possible at noise levels above L_A 75 dB.

Preschool teachers reported a high physical and emotional strain due to the noise.[6],[26] Whereby the duration of employment and age plays an important role. Eysel-Gosepath *et al*.[6] found that 90% of preschool teachers who have been in the profession for 20 years or more, and 72% of preschool teachers aged 46 and over feel more stressed by noise today than in the past.

Extra-aural noise effects could be found in several studies, with responses to noise stimuli based on the general stress theory.[27] A significant increase in noradrenalin was described from Ising and Maschke[28] in the case of communication disturbances, caused by traffic noise, at an average level of 60 dB(A). Kraus *et al*.[29] found that increases of five dB(A) within $L_{eq} < 65$ dB(A) resulted in an increase in heart rate (HR). However, for noise ≥65 dB(A), they found that the associations with cardiac functions were less pronounced, and partly in the opposite direction. Therefore, the authors assumed that noise at lower levels may have health effects beyond the "fight-or-flight" response to high noise levels. Kristal-Boneh *et al*.[30] computed the means of resting HR and blood pressure at seven different noise levels for males and females and found a progressive increase with noise intensity. Lusk *et al*.[31] found a positive correlation of HR and blood pressure with noise exposure among workers, whereby HR also significantly increased by activity and stress levels. Amelsvoort *et al*.[32] compared the heart rate variability (HRV) in shift workers between a low noise level category 55 dB(A) and high noise conditions 75, 90, and 100 dB(A). Changes in HRV parameters were found, which might indicate a shift in cardiovascular regulation toward sympathetic dominance with higher noise levels. Tiesler and Oberdörster[12] examined the effects of noise during individual lessons on teachers' HRs. It was shown that the HR (beats/min) was largely synchronous progressing with the sound level (5 minutes), as an indicator of psychophysiological stress. After acoustical refurbishments, the teachers' average HR decreased up to 10 beats/min in the 5 to 10 dB quieter lesson.[12] According to the Environmental Expert Council, there tends to be a consistent trend toward increased cardiovascular risk if the daytime emission levels exceed 65 dB(A).[33]

It has been shown that noise annoyance and noise sensitivity can also lead to physiological reactions in connection with noise exposure.[27] In this context, effects of noise annoyance on the autonomic nervous system[34] and a higher risk of cardiovascular disorders have been found.[35] Noise sensitivity was observed to significantly affect physiological responses.[36] Furthermore, marginally higher HRs were found for the high noise sensitivity group compared to the low noise sensitivity group.[37] In a study of 100 nurses in an intensive care unit, it was shown that noise-induced stress in the workplace has a positive correlation with burnout, the emotional exhaustion scale of the Maslach Burnout Inventory (MBI),[38] but no significant difference was found between noise-sensitive and non-noise-sensitive nurses.

Aim of the Study

Since extra-aural noise effects have already been demonstrated in several studies, the aim of this study was to investigate whether noise in preschools has an impact on the cardiovascular activity of preschool teachers. Noise sensitivity and noise annoyance were considered as possible confounding variables. Since it was established that preschool teachers with higher age and years of service feel more stressed by noise than at the beginning of their profession,[6] it was investigated whether this effect could also be found in the present study. Finally, the study also aimed to provide insight into the health status of preschool teachers in relation to noise-related stress, well-being, stress perception, and burnout risk.

The following research questions were delineated:

- Do noise levels in preschools affect the cardiovascular activity (HR and HRV) of preschool teachers?

- Do noise sensitivity and noise annoyance have an impact on the relationship between noise and cardiovascular activity?
- Do preschool teachers find it more difficult to tolerate noise with increasing duration of employment as well as with higher age?

Methods

The study was planned and prepared as master thesis of the first author and was accepted by the institutional review board of the Faculty of Psychology of the University of Vienna (20101122). Participation in the study was voluntary after the nature of the procedure was explained in detail. Participants were also informed that they could withdraw from the study at any time.

Participants

The study was conducted in nine private preschools in Vienna, involving 23 preschool teachers (22 females and 1 male). The selection criterion was, apart from working as a preschool teacher, a healthy condition without cardiac arrhythmia.

Study Design and Procedure

The research design corresponds to a cross-sectional study, with data collected per individual on 1 day. It was conducted as a "one-shot case study" because no control group was included. The preschool teachers were provided with 24-hour ECGs and asked to fill in questionnaires. The noise level in the classroom was recorded throughout the preschool teachers' working day. A detailed observation took place during the entire study. The recordings varied between 4 and 8 hours, with starting times from 7.30 a.m. to 12.40 p.m. To enable a standardized comparison, the first 4 hours of each preschool teacher's individual working time were selected for the analysis of the correlation of noise level with HR and HRV.

Data Collection

Stationary Sound Recordings

Stationary sound recordings were collected by the use of "DL-160S Sound Pressure Data Logger", Voltcraft®, with an accuracy of about ±1.4 dB, in accordance with EN 61672-1, Class 2. The microphone was placed within the preschool classes, at a height of 1.5 to 2 m above the floor. Sound level was recorded in dB(A) values, according to 10 seconds intervals. In addition to the dB(A) value, the peak level was recorded. The values were converted into equivalent A–weighted sound pressure levels, L_{Aeq}.

For each individual, two equivalent A–weighted sound pressure levels, L_{Aeq} were computed:

(1) In order to calculate the sound level during an average work shift, equivalent A–weighted sound pressure levels for each participant, standardized over the first four working hours, were calculated, $L_{\mathrm{Aeq,4\,h}}$.

(2) Equivalent A–weighted sound pressure levels in 5-minute intervals were calculated over the entire working time of each preschool teacher, $L_{\mathrm{Aeq,5\,min}}$.

Measurements of Physiological Data

The physiological activity was measured with an electrocardiogram (ECG) recorder "TOM Medical Development GmbH." ECGs were recorded with standard Ag/AgCl ECG electrodes. The recorded data were analyzed by the Medilog Darwin program. Five-minute intervals for the cardiovascular activities during the work shifts of the preschool teachers were calculated. Furthermore, mean values from the 5-minute intervals were calculated for each individual during the first four working hours. For further analyses, the HR and the HRV, measured with the pNN10 value, were used. The pNN10 value is a usable and sensitive time domain parameter for cardiovascular activity[39] and is considered a stable parasympathetic marker. It has been shown that low pNNxx parameters (pNN10 - pNN40) correlate negatively with stress and depression and positively with well-being.[40]

Questionnaires

The questionnaires comprised the following blocks: (1) sociodemographic information as well as questions to noise-related stress; (2) psychological characteristics such as well-being, stress, and burnout risk, collected by standardized questionnaires; and (3) perceived noise sensitivity and noise annoyance.

(1) Sociodemographic information included age, gender, years of service, extent of employment, group size, supervision key, availability of acoustic ceiling in the group room, and the option to hold a break. Noise-related stress was measured with a questionnaire specifically developed for a study with preschool teachers in Cologne, Germany: "Erhebungsbogen zu lärmbedingtem Stress für ErzieherInnen in Kindertagesstätten" (Eysel-Gosepath *et al.*, 2010).[6] An English-translated version of this questionnaire can be found in a report on the effects of noise on primary school teachers.[41] Toleration of noise was assessed with the question: "Compared with the beginning of my professional activity, today I find tolerating high sound levels . . . ": (1) harder, (2) unchanged, (3) easier.[6],[41]

(2) *Well-being* was assessed by the WHO-Five Well-being Index (WHO-5).[42] This questionnaire measures current mental well-being (with a time frame over the previous 2 weeks). It contains five items rated on a six-point scale, and the raw score ranges from 0 to 25. A score <13 indicates poor well-being and is an indication for testing for depression under the International Classification of Diseases, Tenth Revision (ICD-10). *Stress* was assessed using the Perceived Stress Questionnaire (PSQ, short version) (Fliege *et al.*, 2005).[43] The PSQ consists of 20 items rated from

(1) almost never, (2) sometimes, (3) often, and (4) usually. It contains the four subscales: "*worries*,", "*tension*," "*joy,*" and "*demands*." The raw scores range from 0 to 100. Sum scores for each subscale and an overall score containing the four subscales can be calculated, with a higher score indicating a greater level of self-reported stress. *Burnout risk* was measured by MBI,[44] which measures three aspects of burnout using 22 items: "*emotional exhaustion*," "*personal accomplishment,*" and "*depersonalization*." The answers are recorded on a 7-point scale. The results are divided into low, medium, and high burnout. The interpretation is made separately for each subscale.

(3) *Noise sensitivity* was assessed by Kurzfragebogen zur Erfassung der Lärmempfindlichkeit" (in German) / engl.: Short questionnaire for the assessment of noise sensitivity.[45] It consists of nine items. The row score ranges from 0 to 27, whereby a high score expresses high noise sensitivity. *Noise annoyance* was examined with the Questionnaire on general noise annoyance (developed by M. Trimmel). It consists of seven statements, which are asked to agree or disagree. The response format is based on an 11-point scale ranging from 0 "not at all true" to 10 "very true." A high score indicates a high level of noise annoyance.

Statistical Analysis

The statistical analyses were performed using SPSS 20.0. A descriptive analysis of the sociodemographic data and the questionnaires (survey on noise-related stress, PSQ, General Well-Being Scale [GWBS], WHO-5, and MBI) was carried out. The correlations between noise exposure, equivalent A–weighted sound pressure level of the first 4 hours ($L_{\text{Aeq,4 h}}$) and physiological data (HR and pNN10), during work shifts, were calculated via Pearson correlations. The possible influences of noise sensitivity and noise annoyance as moderator variables were assessed by partial correlations.

To examine whether the HR and the HRV(pNN10) changes with the magnitude of sound level classes, three classes were calculated over the 5-minute interval sound levels over working time: (1) "low noise" ≤65 dB(A), (2) "middle noise" 66–75 dB(A), and (3) "high noise" 76–85 dB (A). One-way repeated-measures analyses of variance (ANOVAs) were performed to determine whether the cardiovascular parameters change between the three sound level classes. To assess whether there were differences between the three groups, pairwise comparisons were conducted.

To test whether noise sensitivity and noise annoyance have an influence on the change of HR and pNN10 with the level of sound level classes, the differences for the lowest to highest HR and for the lowest to highest pNN10 were calculated. Pearson correlations were performed to test whether the level of these values correlates with noise sensitivity and noise annoyance.

Results

Stationary Noise Recordings within Preschool Classes

The equivalent continuous sound pressure levels for 4 hours ($L_{\text{Aeq,4 h}}$) and the maximum peak level (peak$_{max}$) measured within the preschool classes are shown for each preschool teacher in Table 1.

The equivalent sound pressure level, for the first 4 hours of the preschool teachers' work shifts, ranged from L_{Aeq} 70.3 to 78.6 dB(A) and showed a mean value of L_{Aeq} 74.7 dB(A) (SD = 1.74). The average maximum sound peak$_{max}$ yielded a value of 96.9 dB(A) (SD = 7.31), with a range of 90.8 to 127.6 dB(A).

The sound pressure levels varied over time depending on the activities in the rooms. The lowest sound levels occurred when the children were taking a nap. Figure 1 presents an example of a stationary noise recording in one preschool class.

Sample Characteristics

In Table 2, the sample characteristics are presented. The average age of the educational staff was 31.4 years (SD = 8.6), with a range of 20 to 59 years. Approximately one third (30.4%) reported having own children. The average working time was 32.3 hours per week (SD = 8.6). Fifty-two percent of the preschool teachers had been working in a

Table 1: Equivalent Sound Pressure Levels ($L_{\text{Aeq,4 h}}$) and Maximum Peak Levels (Peak$_{max}$) of the Preschool Teachers (TP01 . . . TP23).

Participant	Time	L_{Aeq} 4 Hours	Peak$_{max}$
TP01	08:50–12:50	73.2	96.5
TP02	08:20–12:20	74.0	99.6
TP03	12:40–16:40	76.3	93.2
TP04	08:50–12:50	75.3	90.8
TP05	08:35–12:35	75.5	98.5
TP06*	09:25–13:15	75.6	93.2
TP07	09:10–13:10	72.5	96.5
TP08	07:35–11:35	73.9	100.1
TP09	08:45–12:45	75.0	98.5
TP10	08:45–12:45	74.3	99.6
TP11	08:20–12:20	77.9	93.4
TP12	08:05–12:05	73.6	95.8
TP13	08:35–12:35	75.4	94.2
TP14	09:00–13:00	75.1	99.9
TP15	10:10–14:10	70.3	99.4
TP16	08:20–12:20	75.4	93.0
TP17	09:05–13:05	74.2	93.7
TP18	09:15–13:15	73.3	92.5
TP19	08:20–12:20	75.4	93.0
TP20	09:25–13:25	73.2	93.0
TP21	11:00–15:00	75.9	92.5
TP22	07:30–11:30	74.7	94.2
TP23	08:30–12:30	78.6	127.6

*Values were only available in this time frame preschool for <4 years, while 48% indicated that they had been working for 4 to >20 years. More than three quarters (78.3%) stated to work with a group size of 20 to 25 children and more than half (56.5%) in a team of two staff.

An acoustic ceiling was only available in group rooms of two preschool teachers. More than half of the participants stated that a break during the working hours is not possible (56.5%).

The majority of preschool teachers described their professional activity as physically and mentally stressful (73.9%) and reported that it is often or always true that they feel tired and exhausted at the end of a working day (82.6%).

Table 2: Sample Characteristics of the 23 Preschool Teachers (22 Female and One Male).

		f	%
Age	20–29 years	11	47.8
	30–39 years	7	30.4
	40–49 years	4	17.4
	50 – 59 years	1	4.3
Own children	Yes	7	30.4
	No	16	69.6
Employment	Part-time	13	56.5
	Full-time	10	43.5
Working time in hours/week	<20 h	1	4.3
	20–37 h	12	52.2
	40 h	10	43.5
Years of service	<1 years	2	8,7
	1–3 years	10	43.5
	4–19 years	8	34.8
	>20 years	3	13.0
Group size	<20 children	3	13.0
	20–25 children	18	78.3
	>25 children	2	8.7
Supervision key	One staff	1	4.3
	Two staffs	13	56.5
	Three staffs	7	30.4
	Four staffs	2	8.7

Health Status of Preschool Teachers

The perception of stress, well-being, burnout risk, as well as the extend of noise sensitivity, and noise annoyance of the preschool teachers is shown in Table 3.

The results of the PSQ total score shows that the preschool teachers' stress experience was in the average range 39.4 (SD = 16.9), with low *Worries* (M = 29.9, SD = 15.8) and an average range in *Tension* (M = 43.8, SD = 21.8) and *Demands* (M = 53.6, SD = 21.5). The *Joy* scale was in the upper range (M = 69.6, SD = 17.5), indicating a high level of joy.

Table 3: Descriptive Analysis of Preschool Teachers' Perception of Stress, Well-being as well as the Extend of Noise Sensitivity and Noise Annoyance.

	N	Min	Max	Mean	SD
PSQ total score	23	16.7	74.6	39.4	16.9
PSQ worry	23	6.7	60.0	29.9	15.8
PSQ tension	23	0.0	86.7	43.8	21.8
PSQ joy	23	33.3	93.3	69.6	17.5
PSQ demands	23	13.3	100.0	53.6	21.5
Well-being (WHO-5)	23	7.0	22.0	14.7	4.5
MBI emotional exhaustion	23	0.33	4.11	1.9	1.1
MBI personal accomplishment	23	4.0	6.0	5.2	0.6
LEF-K noise sensitivity	23	6.0	25.0	14.7	4.3
Noise annoyance	23	3	67	50.0	14.2

PSQ: score ranges from 0 to 100; WHO-5: score ranges from 0 to 25; MBI: emotional exhaustion (low: 0.00–1.75, medium: 1.87–2.75, high: ≥2.87), personal accomplishment scale (low: ≥4.87, medium: 4.00–4.75, high: 0.00–3.88); LEF-K: score ranges from 0 to 27; noise annoyance: score ranges from 0 to 70. LEF-K = Kurzfragebogen zur Erfassung der Lärmempfindlichkeit (in German), MBI = Maslach Burnout Inventory, PSQ = Perceived Stress Questionnaire, WHO-5 = World Health Organization Five Well-being Index

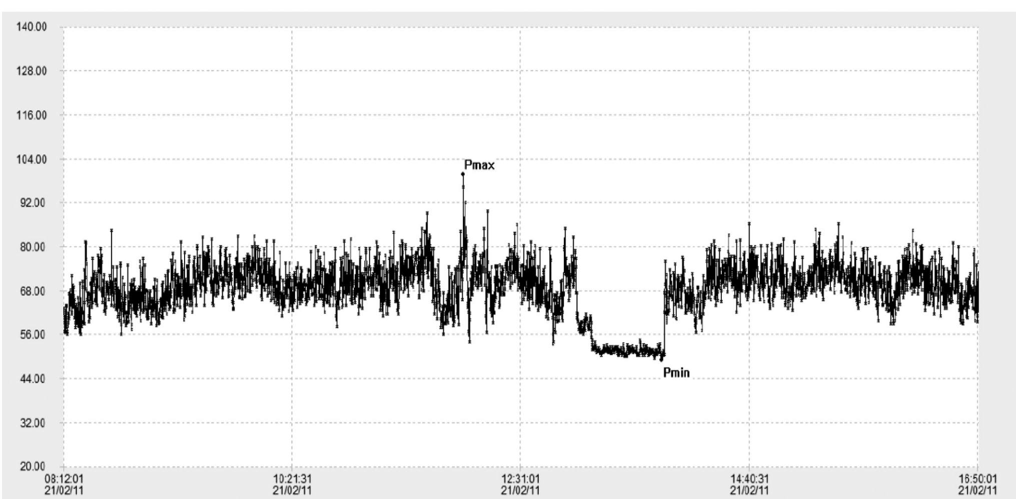

Figure 1: Sound measurement in one preschool class.

The health status of the last 2 weeks was assessed using WHO-5. The mean value was in the average range (M=14.7, SD=4.5). However, seven participants (30%) fell below the stated WHO threshold of 13, which indicates poor well-being and testing for depression according to ICD-10 [Figure 2].

In order to test whether noise-related stress in the preschool has an impact on the well-being status of the preschool teachers, Spearman correlations were calculated for the items of the noise-related stress questionnaire.[6] The results are shown in Table 4. Statistically significantly positive correlations were found regarding "high sound levels result from the group room" ($r_s = 0.593$, $P = 0.003$), "feeling tired and exhausted after work" ($r_s = 0.714$, $P = <$ 0.001), "after work thinking over the day for hours" ($r_s = 0.424$, $P = 0.044$), "voice affected because of speaking loudly very often" ($r_s = 0.525$, $P = 0.010$). Statistically significantly negative correlations were found regarding: "sound level of children do not matter" ($r_s = -0.557$, $P = 0.006$), and "staying calm even at external sound levels" ($r_s = -0.590$, $P = 0.003$).

The risk of burnout was assessed using the MBI. As a low reliability of the depersonalization scale was found (Cronbach $\alpha = 0.2$), this scale was excluded from the analysis. The mean value for *emotional exhaustion* was 1.9 (SD = 1.1), which indicates a low burnout risk in this category. However, four individuals showed a high risk for burnout in this area. The mean value for the *personal accomplishment* scale results in 5.2 (SD = 0.6), which refers to a low burnout risk. To test whether noise-related stress in the preschool has an impact on a higher burnout risk regarding *emotional exhaustion*, Spearman correlations were calculated for the items of the noise-related stress questionnaire.[6] The results are shown in Table 5. Statistically significantly negative correlations were found regarding "high sound levels result in the group room" ($r_s = -0.628$, $P = 0.001$), "feeling tired and exhausted after work" ($r_s = -0.825$, $P = <$ 0.001), and "voice affected because of speaking loudly very often" ($r_s = -0.441$, $P = 0.035$). Statistically significantly positive correlations were found regarding "sound level of children do not matter" ($r_s = 0.573$, $P = 0.004$) and "staying calm even at external sound levels" ($r_s = 0.666$, $P = 0.001$).

The preschool teachers' *sensitivity to noise* was in the medium range ($M = 14.7$, SD = 4.3). The results of the *noise annoyance* score showed a mean value of 50.0 (SD = 14.2), which indicates that the preschool teachers feel rather annoyed by noise.

Results of Cardiovascular Activity

Descriptive data of the preschool teachers' cardiovascular activity (HR and pNN10) are shown in Table 6, calculated over the first 4 hours of the working day. Due to technical and individual issues, one defective ECG device and two cases of medication influence, three individuals had to be excluded from this analysis.

The progress of the sound level and the HR over the working time was graphically depicted for each participant. The 5-minute sound levels were compared with the 5-minute intervals of the HR. Figure 3 shows an example of the correlation of the sound pressure level $L_{Aeq,5\,min}$ and the HR of one preschool teacher during the entire working day.

Correlation between Sound Pressure Level and Heart Rate and Heart Rate Variability (pNN10)

Pearson correlation was used to analyze the association between the sound pressure level during work shift ($L_{Aeq,4\,h}$) and HR as well as HRV (pNN10). The analysis showed a statistically significant positive correlation between

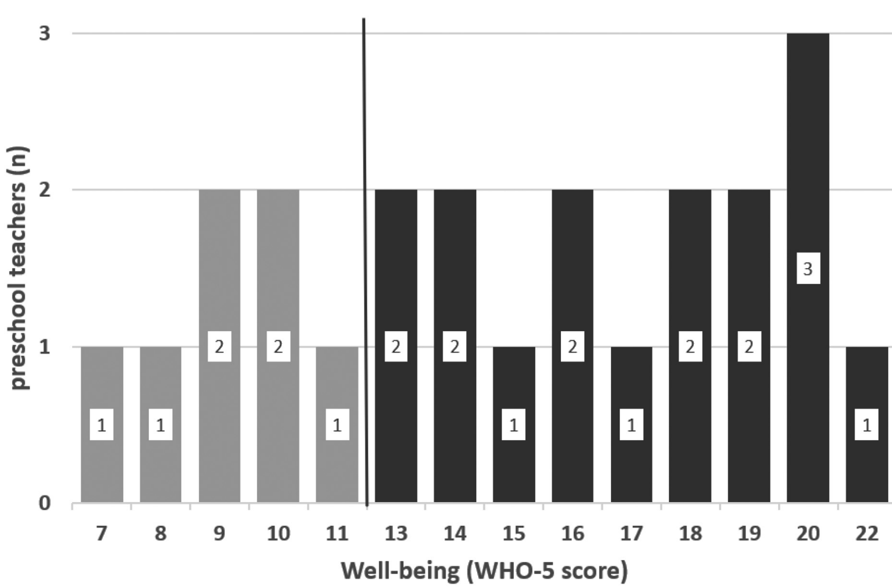

Figure 2: Well-being scores of WHO-5. WHO-5 = World Health Organization Five Well-being Index.

Table 4: Spearman Correlations between World Health Organization Five Well-being Index and Items of the Noise-related Stress Questionnaire.

		High Sound Levels in My Working Place Result from . . .					Sound Levels Produced by Children Seem to be . . .		
		External Sources (Construction Work, Traffic)	Outside Area	Corridor	Gym	Group Room	Louder in the Morning than in the Afternoon	Louder in the Afternoon than in the Morning	I Believe Children are Louder at the Beginning of the Week Than at the End
WHO-5	r_s	0.241	0.163	0.302	0.268	0.593*	0.060	0.045	−0.071
	P	0.267	0.457	0.162	0.217	**0.003**	0.786	0.840	0.753
		Sound Level of the Children do Not Matter	I Stay Calm Even at External Sound Levels	I Suffer from Sleep Disturbance	After Work I Feel Tired and Exhausted	After Work I have to Think over the Day for Hours	I Suffer from Hoarseness and Speech Disturbances	My Voice is Affected because I have to Speak Loudly Very Often	
WHO-5	r_s	−0.557*	−0.590*	0.222	0.714*	0.424**	0.386	0.525**	
	P	**0.006**	**0.003**	0.308	**0.000**	**0.044**	0.069	**0.010**	

Rating scales for the instruments: WHO-5: (0) at no time, (1) some of the time, (2) less than half the time, (3) more than half the time, (4) most of the time, (5) all of the time. Questionnaire on noise-related stress (Eysel-Gosepath *et al.*, 2010): (1) applies always, (2) applies often, (3) applies infrequently, (4) applies never. WHO-5 = World Health Organization Five Well-being Index. $^{*}P < 0.01$. $^{**}P < 0.05$.

Table 5: Spearman Correlations between Maslach Burnout Inventory Emotional Exhaustion Scale and Items of the Noise-Related Stress Questionnaire.

		High Sound Levels in My Working Place Result from . . .					Sound Levels Produced by Children Seem to be . . .		
		External Sources (Construction Work, Traffic)	Outside Area	Corridor	Gym	Group Room	Louder in the Morning Than in the Afternoon	Louder in the Afternoon Than in the Morning	I Believe Children are Louder at the Beginning of the Week Than at the End
MBI emotional exhaustion	r_s	−0.204	−0.113	−0.235	−0.076	−0.628**	0.091	0.001	0.301
	P	0.349	0.608	0.281	0.731	**0.001**	0.681	0.996	0.174
		Sound Level of the Children do Not Matter	I Stay Calm Even at External Sound Levels	I Suffer from Sleep Disturbance	After Work I Feel Tired and Exhausted	After Work I have to Think over the Day for Hours	I Suffer from Hoarseness and Speech Disturbances	My Voice is Affected because I have to Speak Loudly Very Often	
MBI emotional exhaustion	r_s	0.573**	0.666**	−0.324	−0.825**	−0‘.393	−0.341	−0.441**	
	P	**0.004**	**0.001**	0.131	**0.000**	0.064	0.111	**0.035**	

Rating scales for the instruments: MBI *emotional exhaustion scale*: low: 0.00–1.75, medium: 1.87–2.75, high: ≥2.87; questionnaire on noise-related stress (Eysel-Gosepath *et al.*, 2010): (1) applies always, (2) applies often, (3) applies infrequently, (4) applies never. MBI = Maslach Burnout Inventory. $^{*}P < 0.05$. $^{**}P < 0.01$.

the sound pressure level ($L_{Aeq,4\,h}$) and HR, $r = 0.40$, $P = 0.04$ (one-tailed) [Figure 4].

No significant correlation was found between the sound pressure level ($L_{Aeq,4\,h}$) and HRV (pNN10), $r = -0.05$, $P = 0.41$ (one-tailed) [Figure 5].

Noise Sensitivity and Noise Annoyance as Possible Moderator Variables on the Correlation between Sound Pressure Level and Cardiovascular Activity

To test whether noise sensitivity and noise annoyance are moderator variables for the correlation between sound pressure level ($L_{Aeq,4\,h}$) and cardiovascular activity, partial correlations were performed. The result showed that after controlling noise sensitivity and noise annoyance, the correlations between sound pressure level and HR remain statistically significant, $r = 0.41$, $P = 0.04$ (noise sensitivity), $r = 0.43$, $P = 0.03$ (noise annoyance). The correlations between sound pressure level and pNN10 remain without significant result. The results are presented in Table 7.

Table 6: Cardiovascular Activity (HR and pNN10) of Preschool Teachers, during the First 4 Hours of Working Time.

Cardiovascular Activity	*N*	Min	Max	Mean	SD
Heart rate (HR)	20	78.8	105.6	91.1	7.29
Heart rate variability (pNN10)	20	40.3	72.3	60.9	8.47

The Preschool teachers' mean heart rate (HR) was 91.1 beats/min (SD = 7.29), with a range of 78.8 to 105.6. Furthermore, the average mean of pNN10 showed a value of 60.9 (SD = 8.47) and ranged from 40.3 to 72.3. SD = standard deviation.

Change in Cardiovascular Activity (HR and pNN10) with Increasing Sound Level Classes

For this analysis, the calculated 5-minute intervals, $L_{Aeq,5\,min}$, over the entire working time of each preschool teacher were ordered by size and three noise classes were created: (1) "low noise" ≤65 dB(A), (2) "middle noise" 65–75 dB(A), and (3) "high noise" 76–85 dB(A). The corresponding 5-minute intervals of HR and pNN10 were allocated to the noise classes.

Conspicuous values caused by influences other than sound levels were removed (e.g., irritation at the beginning of recording, leaving the room, movement, and nicotine consumption).

Four further cases had to be excluded from this analysis because no data of noise class (1) was available for these participants. Therefore, the calculation was only carried out with 16 preschool teachers. One-way repeated measures ANOVAs were performed to examine a change in HR and pNN10 with respect to the three noise classes. To detect significant differences between the classes, pairwise comparisons were performed using Bonferroni correction. Table 8 shows the mean value of HR and pNN10 of the three noise classes.

Change of Heart Rate with Increasing Noise Classes

As the Mauchly test for sphericity was significant ($P = 0.014$), the degrees of freedom were corrected using Greenhouse–Geisser estimates of sphericity (= 0.69). The result show that the HR was statistically significantly affected by the noise classes, F (1.38, 20.63) = 15.39, $P = < 0.001$, $\eta^2 = 0.51$. Post hoc comparisons using the Bonferroni correction indicated that the mean score of the HR in the "low noise" condition ($M = 84.66$, SD = 7.76) was

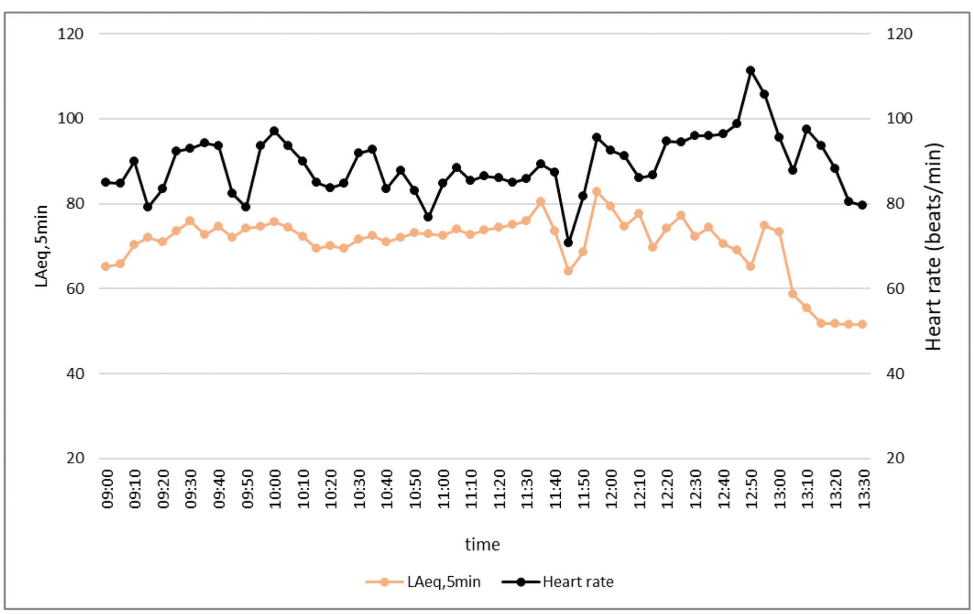

Figure 3: Sound pressure level $L_{Aeq,5.min}$ and heart rate (beats/min) of one preschool teacher.

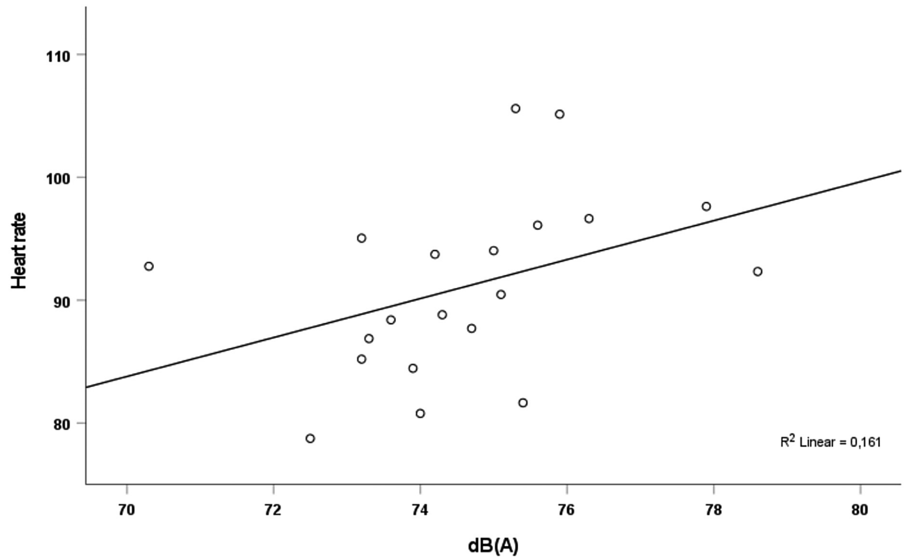

Figure 4: Scatterplot of the correlation between sound pressure level ($L_{Aeq,4\,h}$) and heart rate.

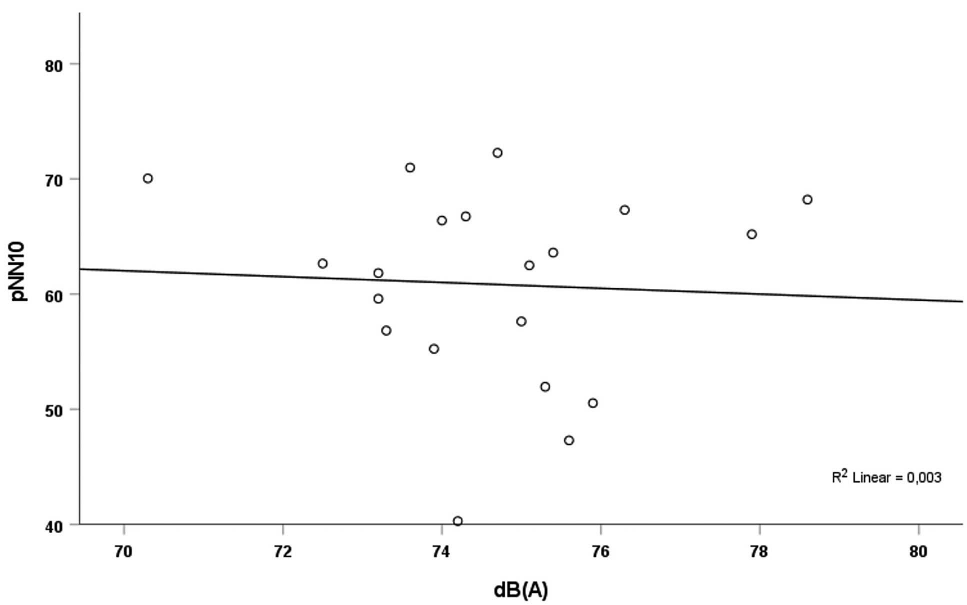

Figure 5: Scatterplot of the correlation between sound level ($L_{Aeq,4\,h}$) and heart rate variability (pNN10).

statistically significantly different than in the "middle noise" condition ($M = 89.38$, SD = 6.55), $P = 0.006$ as well as in the "high noise condition" ($M = 91.11$, SD = 6.29), $P = 0.002$. However, the mean score of the HR in the "middle noise" condition did not significantly differ from the HR in the "high noise condition" ($P = 0.102$). Figure 6 shows the change in HR between the three noise classes.

Change of pNN10 with Increasing Noise Classes

The assumption of sphericity is met ($P = 0.103$). The results show that the pNN10 was statistically significantly affected by the noise classes, F (2, 30) = 9.48, $P = 0.001$, $\eta^2 = 0.39$. Post hoc comparisons using the Bonferroni correction indicated that the mean score of pNN10 in the "low noise" condition ($M = 67.72$, SD = 7.49) was statistically significantly different than that in the "middle noise" condition ($M = 62.67$, SD = 8.30), $P = 0.009$ as well as in the "high noise" condition ($M = 62.06$, SD = 7.22), $P = 0.015$. However, the mean score of pNN10 in the "middle noise" condition did not significantly differ from the pNN10 in the "high noise condition" ($P = 1.00$). Figure 7 shows the change in pNN10 between the three noise classes.

Influence of Noise Sensitivity and Noise Annoyance on the Change in Cardiovascular Activity with Increasing Noise Class

To determine whether noise sensitivity has an influence on the change in HR and pNN10 with increasing noise class, the

Table 7: Partial Correlation between $L_{Aeq,4\,h}$ and Heart Rate and pNN10 Adjusted for Noise Sensitivity and Noise Annoyance.

		Noise Sensitivity		Noise Annoyance	
		HR	pNN10	HR	pNN10
$L_{Aeq,4\,h}$	Partial correlation	0.41*	–0.02	0.43*	–0.03
	P value	0.04	0.47	0.03	0.45

*$P \leq 0.05$ (one-tailed).

Table 8: Mean (Standard Deviation) for Heart Rate and pNN10 of the Three Noise Classes

			95% CI	
	Noise Level	Mean (SD)	Lower	Upper
HR	≤65 dB(A)	84.66 (7.76)	72.99	98.01
	66–75 dB(A)	89.38 (6.55)	77.99	99.22
	76–85 dB(A)	91.11 (6.29)	80.23	103.76
pNN10	≤65 dB(A)	67.72 (7.49)	63.73	71.71
	66–75 dB(A)	62.67 (8.30)	58.25	67.10
	76–85 dB(A)	62.06 (7.22)	58.21	65.91

CI = confidence interval, HR = heart rate, SD = standard deviation.

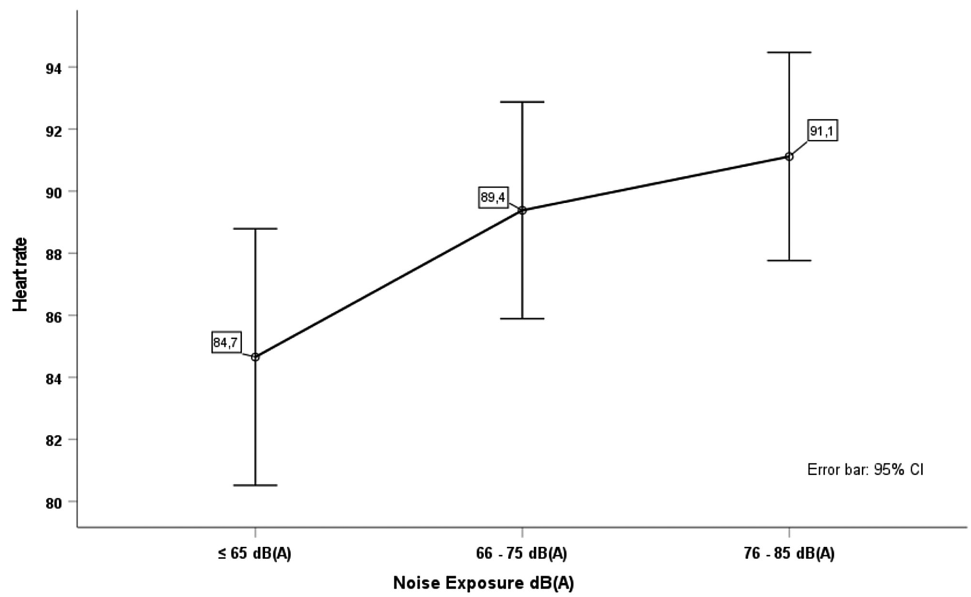

Figure 6: Mean heart rate and 95% confidence interval at different noise classes.

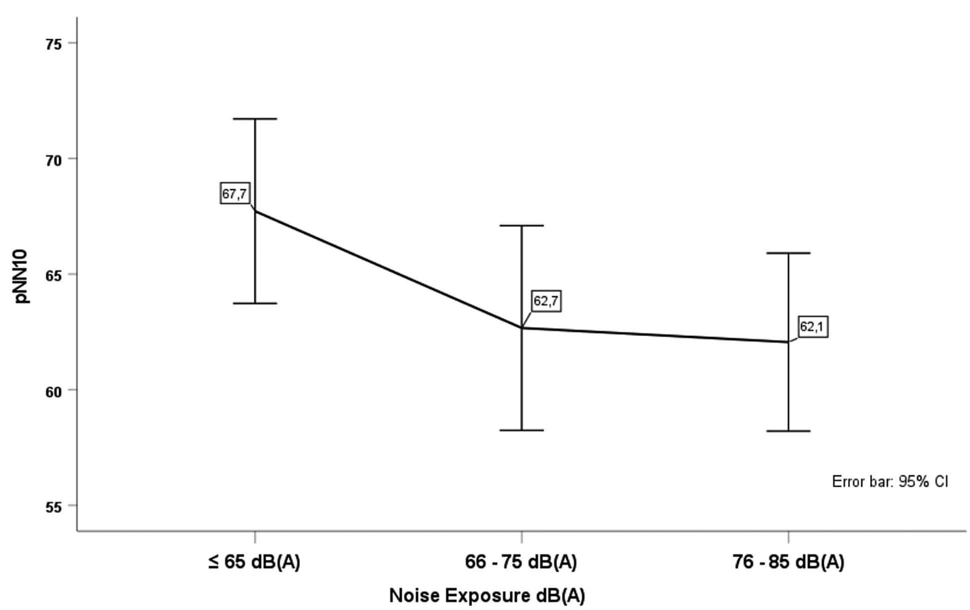

Figure 7: Mean values and 95% confidence interval of heart rate variability (pNN10) at different noise classes.

difference in HR as well as in pNN10 between the low noise class ≤65 dB(A) and the high noise class 76–85 dB(A) was calculated. The difference in HR between low and high noise class showed a median of 8.36 (SD = 5.98, min = −10.49, max = 14.62) beats/min, and the median for the difference in pNN10 between low and high noise class was −3.74 (SD = 6.90, min = −17.73, max = 7.83). To prove if there is a possible correlation between the low and high noise class difference' and noise sensitivity as well as noise annoyance, Pearson product-moment correlations were calculated. No significant correlation was found between the HR and noise sensitivity, $r = 0.23$, $P = 0.20$ There was also no significant correlation between the pNN10 and noise sensitivity, $r = -0.36$, $P = 0.08$. Furthermore, no significant correlation was found between HR and noise annoyance, $r = -0.06$, $P = 0.41$, and pNN10 and noise annoyance, $r = -0.02$, $P = 0.47$.

This indicates that noise sensitivity has no influence on the change in cardiovascular activity with increasing noise class.

Toleration of Noise with Increasing Age and Increasing Years of Service

To verify whether tolerating noise becomes more difficult with increasing age and increasing years of service, the participants were split into groups. Based on the median of years of service (MD = 3.0) a distinction was made between individuals who have been employed for up to 3 years and those who have been employed for 4 or more years (<3, ≥4 years). Furthermore, two age groups were build (<30, ≥31 years) based on the median (MD = 30.0).

Table 9 shows the descriptive characteristics of the age and years of service groups.

Table 9: Descriptive Characteristics of Age and Years of Service Groups.

Categories	*n* (%)
Years of service (MD = 3.0)	
<3 years	12 (52.2%)
≥4 years	11 (47.8%)
Age (MD = 30.0)	
<30 years	13 (56.5%)
≥31 years	10 (43.5%)

Differences between the groups were tested using chi-square (χ^2) tests. Preschool teachers who have been in their profession for 4 or more years find it statistically significantly harder to tolerate noise today than at the beginning of their carrier ($\chi^2(2) = 7.50$, $P = 0.023$). A trend to statistical significance could be found between the age groups. Preschool teachers in the age group of 31 to 59 years reported to find it more difficult to tolerate noise today than in the beginning of their career ($\chi^2(2) = 5.23$, $P = 0.073$) [Table 10].

Discussion

The number of children per group is comparable to preschools in other countries. In the present study, the preschool classes comprised 20 to 25 children in 78.3% of the cases, supervised by two preschool teachers. Since the Lombard effect occurs mainly in rooms where several groups work side by side on different activities, it is recommended to reduce the number of children in the rooms[2],[3],[5],[8] and to minimize disturbance from background noise as good as possible. In line with the findings that room concepts[4],[10] and different activities the children are engaged in[1],[3],[8],[9] have an impact on noise levels, it is recommended that an activity-based approach be taken in designing and equipping the space. The effect of different room concepts on sound levels in classrooms needs to be further investigated in future research.

The majority of the preschool teachers described their professional activity as physically and mentally stressful (73.9%) and reported that it is often or always true that they feel tired and exhausted at the end of a working day (82.6%). This finding is in line with previous research.[6],[26] The average working time of the preschool teachers in the current study was 32.3 hours per week, and more than half of the participants reported that it is not possible to take a break during working hours.

The experienced stress of the preschool teachers was in the average range, with a high level of joy. In terms of well-being, seven participants (30%) of the current sample were found to fall below the stated WHO threshold of 13, which indicates poor well-being testing for depression according to ICD-10. It was found that items of the noise-related stress questionnaire[6],[42] statistically significantly correlated with well-being. Low well-being of preschool teachers correlated

Table 10: Significant Differences in Age and Years of Service between Toleration of Noise.

	Harder	Unchanged	Easier	Total	χ^2 (*P*)
Years of service (MD = 3.0)					
<3 years	2 (20.0%)	8 (80.0%)	2 (66.7%)	12 (52.2%)	7.50 (0.023)*
≥4 years	8 (80.0%)	2 (20.0%)	1 (33.3%)	11 (47.8%)	
Age (MD = 30.0)					
<30 years	3 (30.0%)	8 (80.0%)	2 (66.7%)	13 (56.5%)	5.23 (0.073)
≥31 years	7 (70.0%)	2 (20.0%)	1 (33.3%)	10 (43.5%)	

*$P \leq 0.05$.

with the statement that high noise levels occur in the group room. Furthermore, low well-being correlated with feeling tired and exhausted after work, thinking about the day for hours, and when the voice is affected by frequent loud speaking. Previous studies have identified the negative effect of background noise on speech perception for children and the risk of developing voice problems for preschool teachers.[1],[7],[9],[21] As seen in the current study, speaking loudly very often also has a high impact on poor well-being. Regarding the risk of burnout, four individuals showed a high risk in the *emotional exhaustion* scale. With regard to the items of the questionnaire on noise-related stress, it was found that indicating a high noise level from the group room had a high effect on the burnout risk for preschool teachers. Furthermore, high effects were found in the correlation of burnout risk and feeling tired and exhausted after work. Moreover, a statistically significant correlation was found between a high risk of burnout and the need to speak loudly very often. A high risk of burnout was also found to correlate statistically significantly with the fact when noise levels matter, as well as with difficulties in staying calm even in the presence of external noise levels.

As described by Tiesler and Oberdörster,[12] the correlation between HR and sound level during working hours was also largely synchronous for individual preschool teachers in the previous study. Therefore, it can be assumed that an increased sound level also results in an increased HR among preschool teachers, as a sign of increased stress.

In prior studies it was found that a higher sound level leads to an increased HR.[12],[29],[30],[31] A statistically significant positive correlation between the sound level and the HR was also found in the present study. However, no significant correlation was found between the sound level and the HRV(pNN10). Noise sensitivity and noise annoyance had no effect as moderator variables in the correlation between sound level and HR. Thus, it can be suggested that the correlation between noise and cardiovascular activity occurs independent of noise sensitivity and annoyance.

In the present study, it was investigated whether cardiovascular activity changes at different noise levels classes. The results are in line with previous studies.[30],[32] With increasing sound level classes, an increased HR with a simultaneous decrease in HRV (pNN10) was found. The HR increases by about 5 beats/min at sound level class 66 to 75 dB(A) compared to sound level class ≤65 dB(A). If the sound level increases to 76 to 85 dB(A), the HR increases by only 2 beats/min and the HRV(pNN10) decreases slightly in the sense of a floor effect. In the pairwise comparisons between the low and medium sound level class as well as the low and high sound level class, statistically significant differences were found. Furthermore, according to the sound level, high effects both in the change in HR and in HRV were found, which is an indicator of practical significance of the results. No significant correlations could be found for the change in HR by sound level classes and noise sensitivity as well as noise annoyance. Furthermore, no significant correlations could be found for the change in pNN10 by sound level classes, and noise sensitivity as well as noise annoyance.

As reported by Eysel-Gosepath *et al.*,[6] it was shown that it becomes more difficult to tolerate noise with increasing years of service. It is interesting to note that in this study, a statistically significant difference in the ability to tolerate noise became apparent after only 4 years of employment than at the beginning of the carrier. In previous research, this result was shown for preschool teachers who had been in their profession for 20 years or more.

Furthermore, a trend to statistical significance between age and the ability to tolerate noise was found. Preschool teachers in the age group of 31 to 59 years reported to find it more difficult to tolerate noise today than in the beginning of their career.

The results of the stationary noise measurements in the preschool classrooms are in accordance with previous findings from different countries. The mean sound pressure level for the first 4 hours of the work shifts was L_{Aeq} 74.7 dB (A) (SD = 1.74), with a range from 70.3 dB(A) to L_{Aeq} 78.6 dB(A). The sound $peak_{max}$ ranged from 90.8 to 127.6 dB(A), with a mean of 96.9 dB(A) (SD = 7.31). According to ÖAL Guideline No. 6/18,[22] the average value of 74.1 dB(A) is just below the mentioned interference level of 75 dB, at which clear speech intelligibility is no longer possible. However, in some expositions the measured sound pressure level exceeded the suggested level limit of 75 dB(A).

Acoustic measures such as sound absorbing ceilings were only present in the classes of two preschool teachers, which shows that the majority of participants of the current study had to work in rooms without acoustic measures. As studies have shown, sound-absorbing measures help to reduce long reverberation times in rooms,[12],[13] which leads to a decrease in stress levels.[12] It is therefore of vital importance that sound-absorbing construction measures are also installed in the preschool classrooms.

Conclusion

In the present study, preschool teachers were exposed to equivalent sound pressure levels of L_{Aeq} 70.3 dB(A) to L_{Aeq} 78.6 dB(A) during their first 4 hours of their work shift. It is important to mention that according to ÖAL Guideline No. 6/18, at an interference level of 75 dB, a clear speech intelligibility is no longer possible. As found in the current study, the fact that preschool teachers perceive that their voice is affected by loud speaking has a negative impact on well-being and leads to a high risk of burnout in terms of emotional exhaustion. The majority of the preschool teachers described their professional activity as physically and mentally stressful and stated that they felt tired and exhausted after a working day. The noise level in classrooms showed an effect on the cardiovascular activity of preschool teachers, which can be considered as an indicator of psychophysiological stress. Since it was shown that the toleration of noise gets harder for preschool teachers already after 4 years of service, it is crucial to take measures to reduce noise in preschool classrooms. Sound absorbing construction measures should be compulsory in every class. Construction measures should also be taken to reduce background noise levels as much as possible. It can be assumed that the Lombard effect also occurs in preschool classrooms. For this reason, approaches should be developed to reduce it as much as possible.

Given the small sample size of the present study, the results should be taken with caution and further research with larger sample sizes is needed. Also, a wider range of ages and years of service should be considered. For future investigations, it would be advisable to use a dosimeter that records the sound level directly on the individuals' bodies. Furthermore, it is important to note that this study did not take into account the environment of the preschools, possible noise exposure from road traffic, or the outdoor activities of the children. Future studies should also consider these factors.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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