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Prevalence of hearing loss in Northern and Southern Germany

Background

Reliable and current information on the prevalence of hearing loss in Germany is crucial for estimating the demand and medium-term outlook for hearing rehabilitation. The epidemiological study HÖRSTAT examined the state of hearing in Northwest Germany. With minor deviations due to alternative weighting features, projections to the entire population indicated a prevalence of hearing impairment according to the World Health Organization (WHO) criterion of approximately 16% [10]. The age-specific prevalence was, however, mostly lower than observed in similar international studies [1, 7, 8].

Extrapolations to a national level based on epidemiological studies conducted on a regional level are likely to raise objections. The particularities of the selected sites might result in an unrecognized – and therefore uncorrected – sample bias, which substantially weakens the reliability of the extrapolation. At about the same time and independent from HÖRSTAT, adults in Aalen, located in Southwest Germany, were audiometrically examined and interviewed, e. g., about hearing aid use, in the study "Hearing in Germany" [5]. The present article presents results from both studies and a comparison with international studies. The data of the two studies were pooled to extrapolate the prevalence and degree of hearing impairment taking the medium-term demographic trend into account.

Methods

Study design

The HÖRSTAT study was based on a stratified random sample derived from the Oldenburg and Emden registration offices. Subjects received an invitation letter and a reminder, if necessary, and were contacted by telephone, when applicable. The response rate was 21% in total and 30% on average in the age group of 40–80 years. The subjects who declined participation in the study in the age groups up to 60 years mostly cited time constraints; higher-age groups mostly indicated "other reasons" for not taking part. The design and conduct of the survey are described in detail elsewhere [10, 11]. For the present analysis, the validated data of 1866 adults were used, 585 subjects from Emden (324 female) and 1281 subjects from Oldenburg (691 female), aged 18–97 years. Pure-tone audiometry was performed according ISO 8253-1:2010 using a 5-dB step size [6].

The Aalen survey was split into three waves and the results were partially published [5]. The first and the third waves in May/June 2008 and May 2009, respectively, were based on a random sample of 15,000 subjects aged 7 years and older, derived from the Aalen registration office. For each 5-year age band, an equal number of addresses of males and females were drawn. The response rate can only be specified for the first wave and was 13%, mainly due to the extremely low participation of young adults. The response rate increased from the middle-age groups on to retirement age and reached a peak in the 65-year cohorts of both genders. After an otoscopic examination, trained personnel conducted pure-tone audiometry in sound attenuation booths using the MA 55 audiometer (Maico) and HDA 200 headphones (Sennheiser). Valid air-conduction thresholds from both ears are available for 1239 adults (645 females).

Pooling the data from the HÖRSTAT and Aalen studies results in 3105 records, so that the extrapolation of hearing impairment prevalence could be based on 111 subjects per gender in 5-year age groups.

Definition of hearing impairment

Hearing impairment followed the WHO classification [13] using the mean of the air-conduction thresholds at 0.5, 1, 2, and 4 kHz (PTA4). Hearing was defined as impaired if PTA4 exceeded 25 dB in the better ear. Comparison of the results as well as pooling of the data requires that substantial differences in calibration can be ruled out. The measurement data for 18- to 25-year-old participants from both studies were used to check whether this assumption holds. For these very young adults, major differences in hearing thresholds were neither expected nor could be tolerated. Grouped median hearing thresholds at 0.5, 1, 2, and 4 kHz differ by 0.6 on average (1.2 dB maximum) in this age group. There is, therefore, no evidence for calibration differ-

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Table 1 Control criteria of the weighting model

Weighting models		Effectivity (%)	Critical sample weights (%)
ESP			
–	Emden	80	1.2
–	Oldenburg	93	0
–	HÖRSTAT	90	0
–	Aalen	65	2.1
–	HÖRSTAT + Aalen	86	0
–	–	–	–
Destatis for 2015	–	–	–
Gender, age	HÖRSTAT + Aalen	85	0.6
Gender, age, education	HÖRSTAT + Aalen	72	2.4

ESP European Standard Population, *Destatis* Federal Statistical Office
Sample weights ≤0.3 and ≥3 were defined as critical. The oldest age group comprises population shares for 80 years and over (for weightings at the study level) and 85 years and over (for weighting of the pooled data)

Table 2 Prevalence and number of hearing-impaired adults according to data from the HÖRSTAT and Aalen studies[a]

Weighting features	Gender, age, professional education	Gender, age		
	2015	2015	2020	2025
PTA4 in better ear	Proportion (%), 95% CI	Proportion (%), 95% CI	Proportion (%), 95% CI	Proportion (%), 95% CI
>25 db HL	16.2 (14.7–17.7)	15.2 (13.8–16.6)	16.1 (14.7–17.5)	17.1 (15.7–18.5)
>30 db HL	11.9 (10.6–13.2)	11.2 (10.0–12.4)	12.0 (10.8–13.2)	12.7 (11.4–14.0)
>35 db HL	8.4 (7.2–9.6)	7.9 (6.9–8.9)	8.5 (7.4–9.6)	9.0 (7.9–10.1)
>40 db HL	5.8 (4.8–6.8)	5.5 (4.6–6.4)	5.9 (5.0–6.8)	6.4 (5.5–7.3)
–	(Cases/million)	(Cases/million)	(Cases/million)	(Cases/million)
>25 db HL	11.1 (10.0–12.1)	10.4 (9.5–11.3)	11.1 (10.2–12.1)	11.7 (10.8–12.7)
>30 db HL	8.1 (7.2–9.1)	7.7 (6.8–8.5)	8.3 (7.4–9.1)	8.7 (7.8–9.6)
>35 db HL	5.7 (5.0–6.5)	5.4 (4.7–6.1)	5.9 (5.1–6.6)	6.2 (5.4–6.9)
>40 db HL	4.0 (3.3–4.6)	3.8 (3.2–4.4)	4.1 (3.5–4.7)	4.4 (3.8–5.0)

[a]Estimates on the basis of the official population projection [3] and the distribution of professional educational levels according to the microcensus [2]. Possible cohort effects are not considered. The 95% confidence intervals (*CI*), calculated using an effective sample size and z-statistic approach, are reported in parentheses

ences that need to be taken into account in the analysis.

Sample weights

To compare the study results, the distributions of gender and age were adjusted to the European Standard Population (ESP, [4]). Adjustment to ESP facilitates the comparison of results from different studies by defining the age distribution with equal gender shares. For the purpose of extrapolation, the study data were pooled and adjusted to the gender and age distribution according to the population projection for the years 2015 and subsequent years [3]. The weighting factors are calculated as the ratio of target and effective share of respective subgroups. Professional education was the lowest common denominator to describe the social composition of both study samples. The categories used were "without formal vocational qualification," "vocational training (apprenticeship)," "trade and technical school (technicians, foreman)," and "university degree." The distribution in the pooled data was adjusted to the distribution of professional education levels in the microcensus data [2] for three age groups (≤34, 35–64, 65+ years) disregarding the minor difference in the lower age limit. The appropriateness of these weighting models is reported as effectivity (Kish's approximation [9]) and the proportion of critical low or high weighting factors (**Table 1**).

Results

Comparison of study samples

Fig. 1 shows the age distribution for the HÖRSTAT and Aalen study samples and the pooled data as well as for Germany [3] and according to ESP [4]. Compared with the overall population, the younger and medium-aged groups were underrepresented in the HÖRSTAT and even more so in the Aalen study sample. Females were slightly overrepresented. Higher levels of school and professional qualifications were disproportionately represented in both study samples.

Fig. 2 shows the distribution of professional educational levels by study location and in the overall population. The Oldenburg sample is more strongly biased toward higher professional education than the Aalen and the Emden samples. Adjusted for gender and age, the proportion of participants with a university degree amounts to 31% in the HÖRSTAT (with the study locations Oldenburg and Emden) and 27% in the Aalen study, and is thus about twice as high as in the general population (14%).

Comparison of hearing loss

Fig. 3 shows the cumulative distribution of PTA4 in the better ear for the ESP-adjusted study samples from Aalen, Emden, and Oldenburg. The PTA4 values observed in the Oldenburg sample are slightly better than in the Emden and Aalen study groups. The comparison of the PTA4 distribution for different age groups in **Fig. 4** shows that hearing loss is more pronounced in adults younger than 60 years in the Aalen sample than in the Oldenburg and Emden samples. For age groups 60 years and older, PTA4 values in the Emden sample were worse

than in the Aalen and Oldenburg samples. Adjusted to ESP, the prevalence of hearing impairment was 17.1% in Emden, 14.4% in Aalen, and 13.0% in Oldenburg.

International comparison

As the PTA4 distribution is very similar in the HÖRSTAT and in the Aalen studies, it essentially remains unchanged in the pooled data (**Fig. 4**). The prevalence of hearing impairment in the pooled data is lower than in international studies, for which the gender- and age-specific prevalence of hearing impairment according to the WHO criterion was reported for adults between 20 and 80 years of age [1, 7, 8]. Owing to the high prevalence of hearing impairment in age cohorts over 80 years, the prevalence rates in the present study are expected to be considerably lower than in samples without this upper age limit. If age groups from 20 to 80 years only are included, the prevalence of hearing impairment in the present study is reduced to 10.8% in the pooled data. With the same age limits set, prevalence rates were 15.3% in the U.S. NHANES data [8] and 16.0% in the Norwegian HUNT study [1]. In the Swedish study of Johansson and Arlinger [7], which excluded subjects with a strong exposure to occupational noise, prevalence using a slightly different criterion (PTA4 ≥ 25) and with adjustment to ESP amounted to 18.6%.

Extrapolation and projection

Table 2 summarizes the prevalence of hearing impairment according to the WHO criterion and the prevalence for other PTA4 cut-off values for the years 2015, 2020, and 2025. Assuming the gender and age distribution estimated in the current population projection, the prevalence of hearing impairment according to the WHO criterion is 15.2% in 2015, with 10.4 million adults affected. In future, the absolute number of hearing-impaired adults is expected to increase annually by 150,000–160,000 adults owing to demographic changes, if cohort effects are excluded. This corresponds to a prevalence increase of approximately 1% per 5-year period.

Mild hearing impairment according to the WHO classification prevails. Moderate and severe-to-profound hearing loss with PTA4 >40 in the better ear affected 5.5%, i.e., 3.8 million adults, in the year 2015. This extrapolation is a conservative estimate, because it only considers the distribution of gender and age. If the distribution of professional educational levels is also considered and the bias toward higher educational strata in the study samples is approximately corrected, the prevalence estimate increases by 1.0 to 16.2% for the year 2015. This corresponds to 11.1 million adults.

Hearing aid use

The participants were asked about the uptake and use of hearing aids during a standardized interview in the HÖRSTAT study and using a questionnaire in the Aalen study. Adjusted to the population statistics, 5.2% of the participants were fitted with hearing aids in the pooled data. The proportion varies by location and is 3.5% in Aalen and 6.0% in Emden. In the Oldenburg sample, which showed the lowest prevalence of hearing impairment, 6.1% of the participants also owned at least one hearing aid. Analysis based on the receiver operating characteristics (ROC) showed that the participants in HÖRSTAT were more likely to be fitted with hearing aids, even in cases of milder hearing loss, than in the Aalen study sample (ROC analysis with PTA4 as predictor for hearing aid possession). The maximum of the Youden index (sensitivity + specificity – 1) refers to 29 dB HL in the Oldenburg, 31 dB HL in Emden, but 38 dB HL in the Aalen sample.

Discussion

The two population-based studies, HÖRSTAT and "Hearing in Germany," examined the pure-tone hearing of adults from random samples drawn in Emden and Oldenburg as well as in Aalen, respectively. The response rates in HÖRSTAT and particularly in the first wave of the Aalen survey were low compared with international studies, due to the low response in young age groups. To estimate the prevalence of hearing impairment ac-

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Prevalence of hearing loss in Northern and Southern Germany

Abstract

Background. The HÖRSTAT study conducted in Northwest Germany found hearing impairment in approximately 16% of adults when applying the World Health Organization (WHO) criterion. However, the robustness of extrapolations to a national level might be questioned, as the epidemiological data were collected on a regional level.

Methods. Independently from HÖRSTAT, the "Hearing in Germany" study examined adult hearing in Aalen, a town located in Southwest Germany. Both cross-sectional studies were based on stratified random samples from the general population. The average pure-tone threshold shift at 0.5, 1, 2, and 4 kHz (PTA4), the prevalence of hearing impairment (WHO criterion: PTA4 in the better ear >25), and hearing aid uptake were compared. Data from the Aalen and HÖRSTAT studies were pooled ($n = 3105$) to extrapolate to the prevalence and the degree of hearing impairment for the years 2015, 2020, and 2025.

Results. Both studies yielded very similar results for PTA4. Weighted for official population statistics, the prevalence of hearing impairment according to the WHO criterion is 16.2% in adults, thus affecting 11.1 million persons in Germany. Owing to demographic changes, the prevalence is expected to increase in the medium term by around 1% per 5-year period. With a similar degree of hearing loss, hearing aid provision differs from place to place.

Conclusion. When adjusted for gender and age to the European Standard Population, the prevalence of hearing impairment observed both in HÖRSTAT and the Aalen sample is considerably lower than reported for international studies. Since the analysis refers to cross-sectional data only, possible cohort effects are not considered in the prevalence projection.

Keywords

Persons with hearing impairment · Projections and predictions · Epidemiology · Geographic locations · Demography

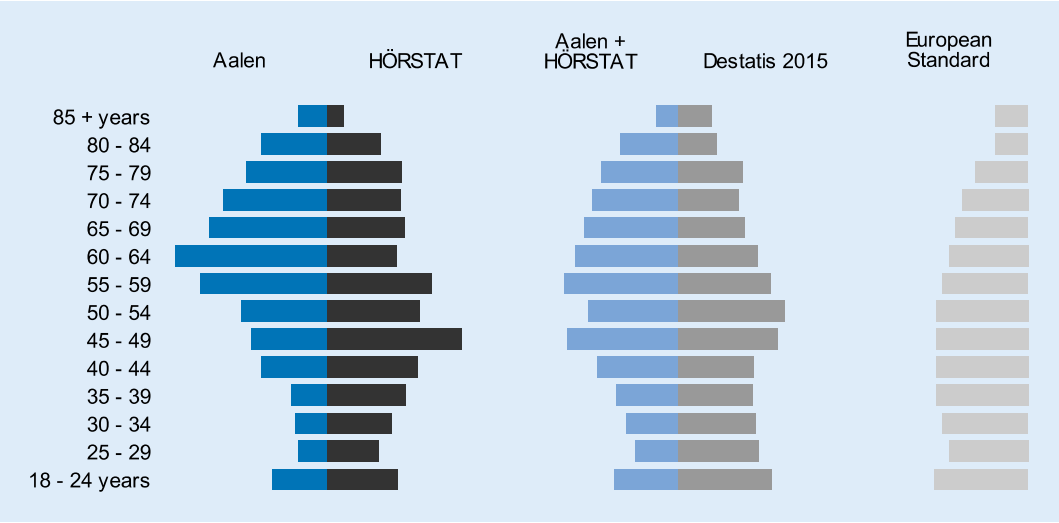

Fig. 1 ◄ Age distribution in the Aalen and HÖRSTAT study samples as well as in Germany [3] and according to the European Standard Population [4]. Age groups of 18 years and older are rescaled to 100%. Differing gender shares are not shown. *Destatis* Federal Statistical Office

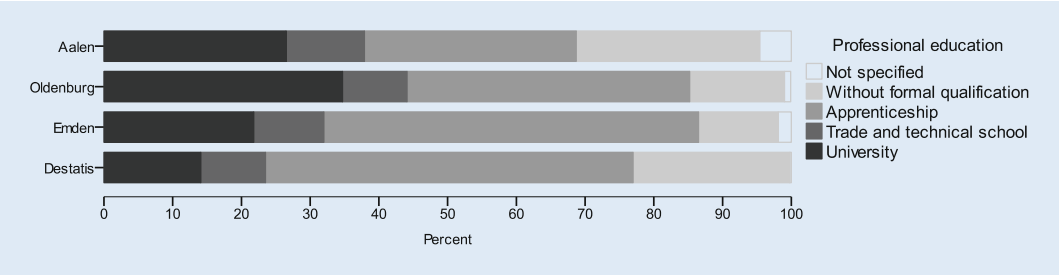

Fig. 2 ◄ Professional education in the Aalen, Oldenburg, and Emden study samples compared with the adult population in Germany [2]

cording to the WHO criterion, however, the age groups between 50 and 80 years are of particular importance. In these age groups, the response rate was well above average. Moreover, the HÖRSTAT study showed that there is no evidence that participants and nonresponders differ in their hearing abilities [10]. The assessment in the highest age groups, however, is subject to greater uncertainty, because the response is presumably linked to more severe health problems, which are possibly associated with a higher prevalence of hearing impairment. Given that approximately 6% of the total population is over 80 years of age and that the average prevalence amounts to 75% in this high age group, the reliability of the estimate seems not to be compromised. If the gender and age distribution is considered, the hearing loss at PTA4 does not differ substantially between the two studies. With respect to the study locations, however, there are notable differences that are related to differences in the social composition of the samples. The association of social class, occupational sector, and puretone hearing was confirmed in HÖRSTAT and is discussed elsewhere [10, 12]. For the pooled data from the HÖRSTAT and the Aalen studies, the level of professional education was the only common feature for comparing the social composition of the samples. Higher educational attainment levels were overrepresented in all three local samples, but were most pronounced in the Oldenburg sample, which showed the lowest hearing loss at PTA4 while the rate of hearing aid use was high. The comparatively high proportion of hearing-impaired people fitted with hearing aids is most probably a result of the longstanding regional PR activities of the Oldenburg hearing research groups. The prevalence rate in the HÖRSTAT study was low compared with international findings, but this low rate was confirmed by the Aalen study. Basically, the low prevalence rate can be traced back to the male participants in the samples whose hearing loss was not as pronounced as reported in earlier international studies. Explanatory factors such as less occupational noise exposure should be considered with regard to the different time points of data collection. These were already discussed in detail for HÖRSTAT [10] and essentially apply to the Aalen study.

To extrapolate the overall prevalence, the age and gender distribution was adjusted to the national data set. The effectivity and the sample weights are at an acceptable level and support the reliability of the extrapolation. The projection is based entirely on the expected demographic change in the age and gender distribution. Effects such as the decreasing share of adults who experienced war time, the improvements in medical and social care, the tightening of noise protection standards, and the further increase in service-oriented occupations are difficult to consider and cannot be assessed with reasonable accuracy. These possible effects, which are more likely to attenuate than to increase the growth in prevalence of approximately 1% every 5 years, are not considered in the projection.

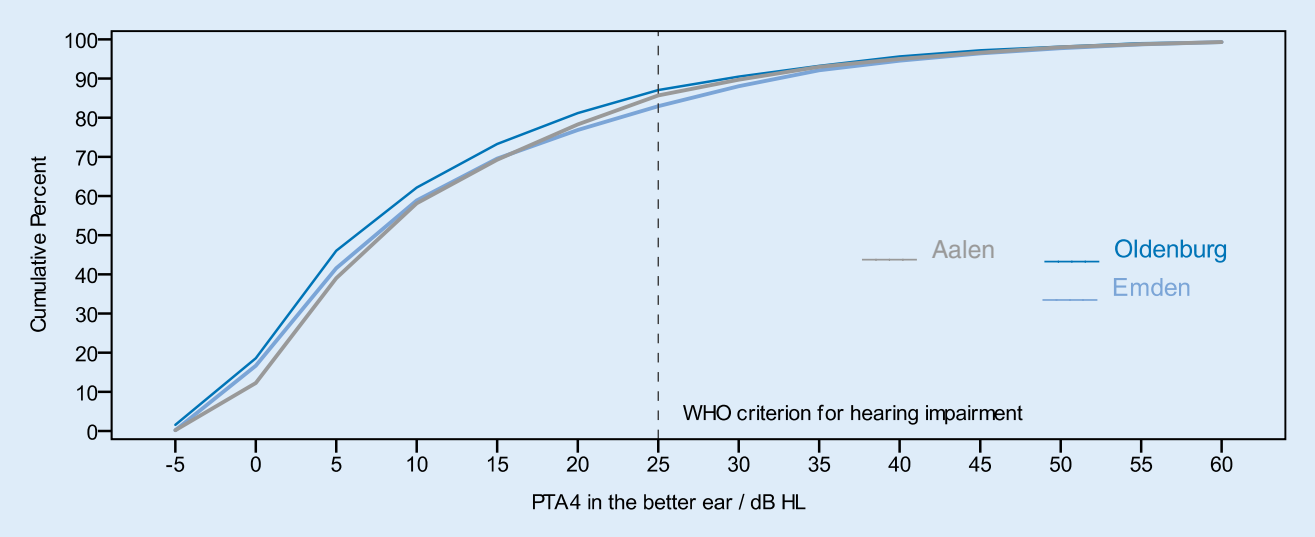

Fig. 3 ▲ Cumulative distribution from 1st to 99th percentile of PTA4 data (better ear) grouped in 5-dB bins in the Aalen, Emden, and Oldenburg study samples. Gender and age distribution adjusted to the European Standard Population. *WHO* World Health Organization

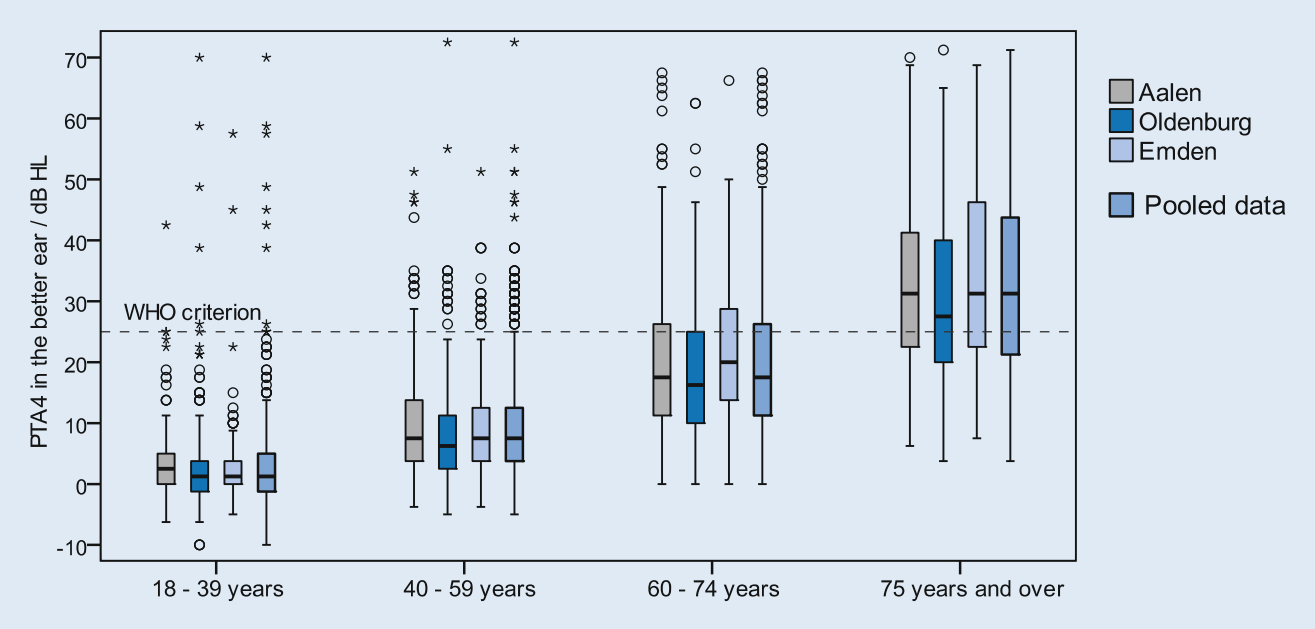

Fig. 4 ▲ Distribution of PTA4 in the better ear in the Aalen, Emden, and Oldenburg study samples, as well as in the pooled data, for four age groups. Gender and age distribution adjusted to European Standard Population. Outliers are marked with *circles* (o) or *stars* (* for extreme outliers). PTA4 data of >73 dB HL are not shown ($n = 6$)

Practical conclusion

- **Without standardization of the gender and age distribution, the overall prevalence is not an appropriate measure for comparing results from different studies.**
- **There are no significant regional differences in the pure-tone threshold data.**
- **In Germany, 11.1 million adults are affected by – mostly mild – hearing loss.**
- **Owing to demographic changes, the overall prevalence is expected to increase by 1% per quinquennium.**

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Compliance with ethical guidelines

Conflict of interest. P. von Gablenz and I. Holube declare that data collection in HÖRSTAT was funded by the Lower Saxony Department of Science and Culture and the European Regional Funding (EFRE). Further analysis was financed from the research fund of the Jade University of Applied Sciences and the federal resources of Niedersächsisches Vorab by the Ministry of Science and Culture of Lower Saxony within the research focus "Hearing in everyday life (HALLO)." The Forschungsgemeinschaft Deutscher Hörgeräte-Akustiker (FDHA) financed the supplementary survey on the German short-form of the SSQ questionnaire. Auritec provided portable Ear 2.0 audiometers. E. Hoffmann declares that the Federal Armed Forces financed the study "Hearing in Germany" and gave further support by providing a mobile examination unit from WTD 91 (Meppen, Germany).

All examinations described in this manuscript were approved by the appropriate Ethics Commission and in accordance with national law and the Declaration of Helsinki of 1975 (in the current, revised version). Informed consent was obtained from all participants.

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