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Smoking and height as risk factors for prevalence and 5-year incidence of hearing loss. A questionnaire-based follow-up study of employees in Denmark aged 18–59 years exposed and unexposed to noise

Tabaquismo y talla como factores de riesgo en la prevalencia y en 5 años de incidencia de hipoacusia. Estudio de empleados en Dinamarca de 18 a 59 años de edad, expuestos o no al ruido con base en un cuestionario de seguimiento

Abstract

This paper investigated whether smoking and short stature in adulthood were independent risk factors for hearing loss. We reanalyzed data from the Danish Work Environment Cohort Study (an existing cohort study), on prevalence of self-reported hearing loss among 7,221 employees and on five-year incidence among 4,610 employees. We found that smoking predicted hearing loss incidence and prevalence. Smoking did not predict incidence at noise exposure during half or more of a worker's hours. Very short stature predicted prevalence in the total adult population only weakly, but strongly among employees born before 1951. These prospective findings indicate that smoking is an independent risk factor for incidence of hearing loss. Very short stature predicted prevalence of hearing loss only in a sub-population.

Sumario

Este trabajo investiga si el tabaquismo y la estatura corta en los adultos son factores de riesgo independientes de hipoacusia. En el estudio danés de cohorte de ambiente laboral, reanalizamos datos de prevalencia de hipoacusia autoreportada en 7,221 empleados y en 5 años de incidencia entre 4,610 empleados. Encontramos que el tabaquismo puede predecir la incidencia de hipoacusia y la prevalencia. El tabaquismo no predijo la incidencia con exposición a ruido en ≥½ de horas de trabajo. La talla muy corta predijo la prevalencia en el total de la población adulta solo débilmente, pero si fuertemente entre empleados nacidos ≤1950. Estos hallazgos prospectivos indican que el tabaquismo es un factor de riesgo independiente en la incidencia de la hipoacusia. La talla muy corta predijo la prevalencia de la hipoacusia solo en una sub población.

In the research literature, exposure to noise is extensively referred to as a risk factor for hearing loss, but overall the etiology of hearing loss is not well described (National Institute of Deafness and Other Communication Disorders, 1996). Most studies on hearing loss were cross sectional and based on few observations, probably due to the high costs of performing the necessary number of audiometric measurements. Apart from noise exposure, other well-established risk factors for hearing loss are genetic disposition, age, gender, and inflammation of the middle ear. Finally, short stature and smoking have been associated with hearing loss. The present paper deals with these possible risk factors as they have been measured in an existing cohort study, the Danish Work Environment Cohort Study (DWECS), (Burr et al, 2003).

Recently, several cross-sectional or retrospective studies have found that smoking (Mizoue, Miyamoto, & Shimizu, 2003; Sharabi et al, 2002; Hong & Kim, 2001; Toppila, Pyykkö, & Starck 2001; Cruickshanks et al, 1998; Cocchiarella, Sharp, & Persky, 1995; Starck, Toppila, & Pyykkö, 1999) is positively related to hearing loss. However, a number of studies have failed to show an association. For example, a recent case control study of hearing loss incidence where smoking has been assessed at follow-up has been published (Nondahl et al, 2004). It has been proposed that the mechanism underlying the relation between smoking and hearing loss is impaired cochlear blood flow (Rao & Fechter, 2000).

In addition, a number of studies have indicated that low birth weight is related to hearing loss (Vohr et al, 2000; Van Naarden & Decoufle, 1999; Sutton & Rowe, 1997). Recently, a register cohort study of a total population of 1,500,000 Norwegians with follow-up periods ranging from 3 to 29 years showed a step-wise increased risk for hearing impairment among term born children with decreasing birth weight (Nafstad et al, 2002). It has been suggested that low body height is an indication of cell cycle delay resulting in impaired hearing (Barrenäs, Landin-Wilhelmsen, & Hanson, 2000). It has been found that adult height is a proxy for

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low birth height and low birth weight (Loos et al, 2001; Pietilainen et al, 2001); and it has been demonstrated that adult height is related to hearing loss among girls and women (Barrenäs, Landin-Wilhelmsen, & Hanson 2000), male workers and conscripts (Barrenäs, Bratthall, & Dahlgren 2003). However, it has not been investigated whether adult height is related to a deterioration of hearing. The reason for such an association could be that adult height can be seen as a marker of fetal deficiencies still operating as risk factors for hearing loss in adulthood.

The aim of the present study was to analyze whether smoking and short stature in adulthood were independent risk factors for prevalence and incidence of hearing loss. If so, confounder control for smoking and short stature needs to be included in future studies on occupational risk factors for hearing loss.

Methods

Population

We reanalyzed data from the Danish Work Environment Cohort Study (DWECS), which was established as an occupational health surveillance study. In DWECS, a representative sample of inhabitants of Denmark, aged 18–59 years, was interviewed in 1990, with a response rate of 90%. The 1990 panel consisted of a simple random sample drawn on 1 October 1990, from the central population register (1/330 of the national population). In 1995 and 2000, everyone in the sample was contacted again, disregarding previous participation or employee status. In 1995 two additional representative samples were drawn on 1 October 1995. The first consisted of people aged 18–22 years; the second consisted of immigrants aged 23–64 years (each sample represent 1/330 of the populations in question). The response rate for the combined 1995 sample was 80%. In 2000 people in the additional samples were contacted again. The design of the study is described elsewhere (Burr et al, 2003).

This design makes it possible to analyze two five-year cohorts, in which the members were employees at base line. The follow-up response rates were 86% in 1995 and 84% in 2000 (Table 1).

The 1990 base line consisted of 6,067 employees; the 1995 base line consisted of 5,652 employees, of which 4,070 also were employees in the 1990 round (Table 1). The cross-sectional analyses in this paper dealt with all employees from the 1990-base line and the new 1,582 employees from the 1995-base line, in total 7,649 people. The number of people excluded from the analysis were 428; of these 16 people, aged 60 or over were considered as a highly selected group on the Danish labour market (Larsen, 2004), 99 were of non-Nordic origin – and thus shorter – making it difficult to analyze height and hearing, 126 people were suffering from a head injury which is known to affect hearing, 187 people had missing information on one or more of the variables used in the analyses. Therefore, the cross-sectional analysis covered 7,221 employees, including 1,486 newcomers from the 1995 round.

The combined 1990–1995 and 1995–2000 cohort consisted of 9,750 observations (Table 1) covering 6,314 people. The base lines of the cohorts shared 4,070 people, but as 634 of them did not take part in the 2000 follow-up, only 3,436 people took part in the follow-ups to both cohorts. A total of 2,221 observations on 1,548 people were excluded from the cohort analyses; of these 100 people were aged 60 years or more in the 1995 base line, 1,033 people in the 1990–1995 cohort not being employees in 1995 were for this reason not asked about their hearing (in the 1995–2000 cohort everyone was asked about hearing at the 2000 follow-up), 107 observations were of non-Nordic origin, 158 observations suffered from a head injury, 223 observations had missing information on one or more of the variables used in the analyses and 600 observations suffered from hearing loss at base line. Therefore, the basis of the follow-up analysis was 7,529 observations on 4,766 people, of which 2,763 people were observed twice.

Table 1. The two 5-year cohorts in the Danish Work Environment Cohort Study, including the number of participants at base line and follow-up, and the number of people leaving and entering the cohorts

	1990–1995 cohort	*1995–2000 cohort*
= Employees at base line who took part in prior cohort	•	4,070
+ New young employees at base line	•	550
+ New adult employees at base line	•	1,032
= Employees at base line	6,067	5,652
− Dead or emigrated in the follow-up period	127	144
− Not interviewed at follow-up	837	861
= Participants at follow-up	5,013	4,647
− Not employees at follow-up	1,033	•
= Employees at follow-up	4,070	•

Variables

The main purpose of DWECS is to give a broad picture of a range of occupational exposures (mainly ergonomic and psychosocial), symptoms and diseases. Therefore the study lacks detailed information on topics such as occupational history, family history of hearing loss, and intake of ototoxic medication. Thus, most themes such as noise and hearing loss were assessed with only one question.

Age and sex

Data on age and sex were obtained from the central population register. All other variables were based on interviews at the respondents' home, either by telephone (preferably) or in person. The number of in-person interviews in the cross-sectional analysis was 682 or 9.4% of all interviews; and at base line in the follow-up analysis, it was 586 or 7.8% of all interviews. The interviewers were staff at the Danish National Social Research Institutes Survey Unit (SFI Survey) with extensive experience in interviewing. They received six hours' training in the questionnaires used, in which researchers and interview managers took part.

Hearing loss

Hearing loss was assessed by means of one yes-no question: 'Do you have reduced hearing to such an extent that you feel it is difficult to follow a conversation between several people without using a hearing aid?'. This question is similar to questions in other studies (National Institute of Occupational Safety and Health 2000; Lutman, Brown, & Coles, 1987; High, Fairbanks,

& Gloric, 1964). Another question ('Do you feel you have a hearing loss?') yielded reasonable sensitivity and specificity; it was minimally affected by age and gender (Sindhusake et al, 2001; Nondahl et al, 1998).

Occupational noise

Occupational noise was assessed by means of one question: 'Are you exposed to noise so loud that you have to raise your voice to speak to someone?'. The answers were combined into three groups: 1) No (for responses of 'seldom' or 'never'), 2) Low (for responses of '1/4 of working hours'), and 3) High (for responses of 'all working hours', '3/4 of working hours', or '1/2 of working hours'). This is fairly comparable to a question used by the National Institute of Occupational Safety and Health (Morata, 2000), which is: 'In your present job, are you currently exposed to loud noise (that is, noise so loud that you must speak in a raised voice to be heard by someone 3 feet away?'. Assuming that the normal level of speech lies within the range of 60–65 dB(A), the present noise exposure question has a high sensitivity, but a fairly low specificity concerning exposure to levels of noise, generally accepted to induce hearing impairment.

Height

Height was assessed by means of one question:'What is your height?. If an individual took part in two rounds of the study, height was included in the analysis as a mean of the two heights reported. If an individual took part in three rounds of the study, height was included in the analysis as a mean of the two heights reported with the shortest distance. In the logistic regressions, people were divided into four groups based on standard deviations and means in the respective gender among the cross-section of employees in 1990 and new employees in 1995. For example, the very short group was below one standard deviation (6.8 cm for males, and 5.9 cm for females) below the mean height (179.3 cm for males, and 166.7 cm for females). The short group was below the mean height but above one standard deviation below the mean height (155–172 cm for very short males; 173–179 cm for short males; 180–186 cm for tall males; 187–206 cm for very tall males; 140–160 cm for very short females; 161–166 cm for short females; 167–172 cm for tall females; and 173–192 cm for very tall females).

Smoking status

Smoking status was divided into four categories: never, formerly, currently <15 g per day, and currently $=>15$ g per day.

Ethnicity

Ethnicity was divided into two groups, Nordic origin and other origin, based on free text answers to the open question: 'Which ethnic group do you belong to?'.

Head injury

Head injury was based on the answer: 'Yes, in the head', to the question: 'Have you ever after an accident either in or outside your job, had long-lasting injuries in head, neck, shoulders, hands, lower back or knees, of which you today still suffer from the after-effects?'.

Analysis

Prevalence and incidence of hearing loss were estimated in both simple cross tabulation analyses and in multiple regression analyses where age, occupational noise, height and smoking were independent variables. As some people are measured twice in the cohort study, the variance estimation has taken this into account.

We calculated Spearman's rank correlations between the independent variables age, noise and height in order to see if any of the variables should be correlated in the population under study. In the combined cross-section of 7,221 employees, including 1,486 newcomers from the 1995 round, most associations were small (correlation <0.10). The strongest was found between height and age (males: correlation -0.28, $p=0.00$, females: -0.16, $p=0.00$). If we disregard previous smokers and thus consider smoking as an ordinal variable (with the categories non-smokers, current smokers <15 g per day, and current smokers $>=15$ g per day), smoking was associated with age (0.24, $p=0.00$ for males, and 0.09, $p=0.00$ for females), noise (0.10, $p=0.00$ for males, and 0.07, $p=0.00$ for females) and height (-0.10, $p=0.00$ for males).

In order to look for possible interactions between occupational noise and smoking, odds for the incidence of hearing loss were estimated in three strata of noise exposure in a multiple logistic regression analysis with age (as a continuous variable) and smoking at base line as independent variables. This analysis was not stratified by gender in order to avoid small numbers in some cells.

Results

Prevalence of hearing loss

Table 2 shows the prevalence of hearing loss among a representative sample of male and female employees in Denmark by age, occupational noise, height and smoking. The observed prevalence was higher among males (9%) than among females (5%) and in both genders the observed contrast in hearing loss was strongest between groups defined by age. In the multiple regression analysis, the contribution of height to the model was borderline significant among males but not among females. However, the odds ratio for very short people versus very tall people was significantly elevated among females but not among males. Moreover, the contribution of smoking to the model was borderline significant among females, but not among males, whereas the risk for both heavy male smokers and for light female smokers was elevated. Note that the observed contrast in prevalence of hearing loss becomes much weaker in the multiple regression analyses, where all independent variables are controlled for simultaneously. As mentioned above, height is strongly correlated to age.

Among employees older than 30, the prevalence of hearing loss was higher among males than females (Table 2). For example, the observed prevalence among 30–39 year-old and 50–59 year-old males was 6% and 20% respectively, and among females 3% and 10% respectively. An additional analysis stratified by occupational noise exposure shows, that the observed prevalences were slightly lower among employees not exposed to occupational noise compared to employees exposed to occupational noise at least half of their working hours (among 30–39 year-old and 50–59 year-old males: 6% and 16% respectively; and among females 3% and 10% respectively). Among employees exposed to occupational noise for at least half of their working hours, the observed prevalences for 30–39 year-

Table 2. Prevalence of hearing loss among a representative sample of 7,221 employees in Denmark (5,735 employees in 1990 and 1,486 employees in 1995) of Nordic origin, aged 18–59 years without head injury

			Multiple logistic regression†		
	n	*Observed prevalence* of hearing loss. %*	*Odds Ratio*	*95% confidence interval*	*P*‡
MALES					
Age					<0.0001
18–29 years	*1427*	4	1		
30–39 years	*940*	7	1.88	1.30–2.73	
40–49 years	*789*	12	3.07	2.14–4.40	
50–59 years	*546*	20	5.58	3.87–8.06	
Occ. noise					<0.0001
No	*2686*	7	1		
Low	*366*	10	1.83	1.25–2.68	
High	*650*	16	2.97	2.27–3.88	
Height					0.05
Very tall (= >187 cm)	*602*	6	1		
Tall (180–186 cm)	*1358*	6	0.82	0.55–1.23	
Short (173–179 cm)	*1146*	11	1.18	0.80–1.75	
Very short (= <172 cm)	*596*	14	1.28	0.84–1.95	
Smoking					0.10
Never	*1306*	6	1		
Former	*640*	12	1.54	1.08–2.19	
Current, <15 g/day	*632*	9	1.31	0.90–1.91	
Current, > =15 g/day	*1124*	11	1.37	1.00–1.89	
Total, males	*3702*	9			
FEMALES					
Age					<0.0001
18–29 years	*1233*	4	1		
30–39 years	*909*	3	0.89	0.55–1.43	
40–49 years	*904*	8	2.08	1.40–3.10	
50–59 years	*473*	10	2.59	1.67–4.02	
Occ. Noise					0.003
No	*2691*	5	1		
¼ of working hours	*228*	4	1.00	0.51–1.94	
= >½ of working hours	*600*	8	1.82	1.29–2.58	
Height					0.13
Very tall (= >173 cm)	*582*	3	1		
Tall (167–172 cm)	*1349*	5	1.39	0.82–2.34	
Short (161–166 cm)	*1054*	6	1.66	0.97–2.82	
Very short (= <160 cm)	*534*	7	1.89	1.07–3.36	
Smoking					0.05
Never	*1421*	4	1		
Former	*567*	6	1.50	0.96–2.33	
Current, <15 g/day	*842*	7	1.69	1.15–2.50	
Current, > =15 g/day	*689*	6	1.50	0.99–2.27	
Total, females	*3519*	5			

*Unadjusted.
† Multiple logistic regression with the independent variables of age, occupational noise, height, and smoking stratified by gender.
‡P-value of the variable in the multiple logistic regression.

old and 50–59 year-old males were 13% and 38% respectively, and among females 5% and 10% respectively.

In additional analysis, we restricted the multiple regression analysis of prevalence presented in Table 2 only to an unselected group of older employees, that is to employees born before 1951 (where adult height is considered to reflect environmental conditions to a larger degree than in younger birth cohorts). However, these employees were not older than 55 years (that is before employees with ill-health begin to retire). The odds ratio among very short people versus very tall people among males was 2.60 (1.12–6.07), and among females was 2.74 (1.00–7.49).

Incidence of hearing loss

Table 3 shows the five-year incidence of hearing loss among a representative sample of male and female employees in Denmark without hearing loss by age, occupational noise, height, and smoking. The observed incidence of hearing loss was generally higher among males than among females (Table 3) and in both genders the contrast in incidence of hearing loss was strongest in groups defined by age. For example, the observed incidences among 30–39 year-old and 50–59 year-old males were 7% and 14% respectively, and among females 6% and 9% respectively. A multiple regression analysis of risk factors for the incidence of hearing loss is also presented in Table 3. In both genders, age and occupational noise were strong risk factors. Smoking contributed to the model in both genders, but only borderline significantly among females. Odds for heavy smoking were higher than for light smoking among both genders; the association was stronger among males than among females. Odds for height were non-significant with the opposite tendencies for the two genders – elevated for females and lowered for men. Note that the strong contrast in the observed incidences disappears in the multiple regression analysis, where we also control for age.

If the analysis of incidence presented in Table 3 was restricted only to people born before 1951, but not older than 55, the association between the independent variables and hearing loss were the same as for the whole cohort.

Table 4 shows the incidence of hearing loss stratified by occupational noise exposure. The contrast in observed incidences in groups defined by age was strongest in the stratum with occupational noise exposure for one quarter of their working hours. This picture is also reflected in the multiple logistic regression, where age predicts hearing loss most strongly in the stratum with occupational noise exposure for one quarter of their working hours. In the stratum with noise exposure for at least half of their working hours, there was no linear relationship between age and hearing loss. At the stratas 'no noise exposure' and 'noise exposure for one quarter of working hours', heavy smoking (i.e. more than 15 g per day) was associated with incidence of hearing loss. The odds ratio for heavy smoking versus never smoking and the odds ratio for age in the fifties versus in the twenties, were highest in the stratum with noise exposure in one quarter of their working hours, medium in the stratum with no noise exposure, and lowest in the stratum with noise exposure in at least half of their working hours. The same pattern, however insignificant, could be seen if the analysis was stratified by gender. As shown in the unstratified analysis (Table 3), height was not a significant risk factor for incidence of hearing loss and with opposite tendencies in each gender. When stratified for occupational noise and gender, height was not a significant risk factor in any stratum. The pattern for employees not exposed to noise and employees exposed to noise for one quarter of their working hours was the same as for all employees. The odds ratio for very short employees versus very tall employees in the stratum exposed for at least half of their working hours was close to one.

Discussion

Our study indicates that smoking is a risk factor for development of hearing loss – or that smoking is associated with risk factors for hearing loss not measured in this study – as it has been found that smoking is associated with incidence of hearing loss. Adding to the suspicion that smoking leads to hearing loss is that smoking is associated more strongly to incidence of hearing loss than to prevalence of hearing loss. The present study shows that height is only to a limited extent related to prevalence of hearing loss, and not at all to incidence. However, the relation between height and prevalence was very strong among people born before 1951; and in the total population, somewhat stronger among women than among men. It may be that height in certain populations is a proxy for suboptimal growth conditions and is therefore only related to hearing loss in those populations.

Strengths and weaknesses of the present study

The present study has some strengths; it is prospective with a high response rate covering more than 4,000 people and includes possible risk factors other than occupational noise. The study also includes questions on hearing validated in other studies (Sindhusake et al, 2001; Nondahl et al, 1998). The present prospective study makes it possible to identify risk factors prior to the effect. This design also avoids part of the 'common method variance' bias; that is, that the same person reports exposures as well as health status at the same time. However, we do believe that individual reporting of height and smoking is biased by perceived hearing loss. Also, there is a need for large studies to assess the possible effect of the many risk factors suspected to cause hearing loss. The present study had three points of time with measurements, which allowed us to combine two cross sections (1990 and 1995) and two cohorts (1990–1995 and 1995–2000) in order to maximize power of the study. As measurements and clinical data are very costly, use of questionnaires, as in the present study, may thus be an attractive alternative.

The study also has some potential weaknesses. Data were obtained by interview. In the present study, eight to nine percent of all interviews were carried out in person, the rest were telephone interviews. A control for interview method did not change the estimates for height or smoking in the regression analyses. As individuals may neglect their true hearing problems (Hetú et al, 1990; Hallberg & Barrenäs, 1995) self-report data may lead to an underestimation of the true prevalence of hearing loss. On the other hand, as the number of subjects in the present study without hearing loss is much larger than the number of subjects with hearing loss, random measurement error tend to lead to an overestimation of hearing loss. However, in the present study, differences due to gender and age in prevalence and incidence were the same as one could expect (Tables 2 and 3). Also, the present study lacks noise exposure data in leisure

Table 3. Five-year incidence of hearing loss among a representative sample of 4,766 employees in Denmark (of which 2,763 were observed twice [in total 7,529 observations]) of Nordic origin, aged 18–59 years, without base line hearing loss or head injury

			Multiple logistic regression†		
	N of observations	*Observed incidence of hearing loss**. %	*Odds Ratio*	*95% confidence interval*	*P*‡
MALES					
Age					<0.0001
18–29 years	*1261*	4	1		
30–39 years	*1150*	7	1.62	1.12–2.34	
40–49 years	*957*	11	2.78	1.95–3.99	
50–59 years	*515*	14	3.60	2.42–5.36	
Occ. noise					0.0001
No	*2820*	7	1		
Low	*423*	9	1.58	1.10–2.27	
High	*640*	12	1.94	1.45–2.60	
Height					0.56
Very tall (= >187 cm)	*636*	8	1		
Tall (180–186 cm)	*1488*	7	0.79	0.55–1.14	
Short (173–179 cm)	*1201*	8	0.83	0.57–1.19	
Very short (= <172 cm)	*558*	10	0.95	0.63–1.43	
Smoking					0.00
Never	*1441*	5	1		
Former	*746*	10	1.53	1.08–2.18	
Current, <15 g/day	*628*	9	1.60	1.10–2.33	
Current, > =15 g/day	*1068*	11	1.81	1.32–2.49	
Total, males	*3883*	8			
FEMALES					
Age					<0.0001
18–29 years	*971*	3	1		
30–39 years	*1114*	6	2.19	1.38–3.45	
40–49 years	*1077*	8	2.74	1.75–4.30	
50–59 years	*484*	9	3.36	2.04–5.56	
Occ. noise					0.00
No	*2759*	5	1		
¼ of working hours	*290*	6	1.11	0.66–1.86	
= >½ of working hours	*597*	11	2.21	1.61–3.03	
Height					0.45
Very tall (= >173 cm)	*605*	4	1		
Tall (167–172 cm)	*1442*	6	1.35	0.86–2.11	
Short (161–166 cm)	*1069*	7	1.39	0.87–2.21	
Very short (= <160 cm)	*530*	7	1.40	0.83–2.35	
Smoking					0.09
Never	*1512*	5	1		
Former	*671*	6	1.05	0.71–1.54	
Current, <15 g/day	*795*	5	0.90	0.60–1.34	
Current, > =15 g/day	*668*	9	1.52	1.07–2.16	
Total, females	*3646*	6			

*Unadjusted.
†Multiple logistic regression with the independent variables age, occupational noise, height and smoking stratified by gender.
‡P-value of the variable in the multiple logistic regression.

Table 4. Five-year incidence of hearing loss stratified by occupational noise among a representative sample of 4,766 employees in Denmark (of which 2,763 were observed twice [in total 7,529 observations]) of Nordic origin, aged 18–59 years, without base line hearing loss or head injury. Multiple logistic regression.

	Occupational noise																	
	No						*¼ of working hours*						*= >½ of working hours*					
		Incidence, %*		*Multiple logistic regression[†]*				*Incidence*, %*		*Multiple logistic regression[†]*				*Incidence*, %*		*Multiple logistic regression[†]*		
	n of observations	*Males*	*Females*	*Odds Ratio*	*95% confidence interval*	*P[‡]*	*n of observations*	*Males*	*Females*	*Odds Ratio*	*95% confidence interval*	*P[‡]*	*n of observations*	*Males*	*Females*	*Odds Ratio*	*95% confidence interval*	*P[‡]*
AGE						<0.0001						0.004						<0.0001
18–29 years	1603	4	2	1			233	4	3	1			396	6	5	1		
30–39 years	1630	6	5	1.73	1.21–2.47		242	10	2	1.75	0.73–4.21		392	10	13	2.20	1.27–3.80	
40–49 years	1547	9	6	2.37	1.70–3.35		167	14	11	3.77	1.64–8.64		320	22	15	3.72	2.20–6.33	
50–59 years	799	13	9	3.73	2.59–5.38		71	19	12	4.51	1.70–11.99		129	18	8	2.40	1.20–4.81	
SMOKING						0.00						0.26						0.18
Never	2300	4	5	1			263	7	4	1			390	10	11	1		
Former	1049	8	5	1.36	0.99–1.86		147	9	6	1.23	0.54–2.79		221	16	10	1.13	0.67–1.90	
Current, < 15 gr/day	1062	9	5	1.44	1.04–1.98		114	10	4	1.39	0.57–3.41		247	9	7	0.70	0.40–1.26	
Current, > =15 gr/day	1168	9	7	1.74	1.29–2.33		189	13	12	2.12	1.02–4.39		379	13	15	1.27	0.80–2.01	
Total	5579	7	5				713	9	6				1237	12	11			

*Observed, unadjusted.
†Multiple logistic regression with the independent variables gender, age and smoking stratified by occupational noise exposure.
‡P-value of the variable in the multiple logistic regression.

time activities. Moreover, data are obtained with only a 5-year interval, and we have no information on possible exposures in the previous or intermediate period (Table 1). The duration of base line exposures is also unknown.

In conclusion, it is most likely that the study underestimates the real associations between the risk factors and hearing loss.

Smoking
We found that smoking was a risk factor for the incidence of hearing loss among both males and females (Table 3). Our prospective findings indicate that smoking is a causal factor for development of hearing loss. However, it is possible that smoking is associated to factors not measured in the study (e.g. leisure time noise exposure or other unknown risk factors for hearing loss). On the other hand we do not think that this confounds results considerably, as smoking is very prevalent in the Danish population, also in subgroups with an otherwise healthy life style. Since smoking was related to occupational noise exposure and age in the study population (see Methods), it should be noted that all associations are controlled for simultaneously (Table 2, 3, and 4). The correlation between smoking and occupational noise was weak. That is, the contrast in smoking between people unexposed to noise and exposed to noise was relatively small, because smoking as mentioned is still very prevalent in Denmark. Information on hearing protector usage is lacking in the study, therefore we underestimate the effect of occupational noise, which in turn may contribute to an overestimation of the odds ratios of smoking.

Smoking has been found to be independently associated to prevalence of hearing loss in a number of studies (Nakanishi et al, 2000; Cruickshanks et al, 1998; Noorhassim & Rampal, 1998; Cocchiarella, Sharp & Persky, 1995) while other studies have failed to identify smoking as an independent risk factor (Nondahl et al, 2004; Palmer et al, 2002; Starck, Topila & Pyykkö, 1999) or even associate smoking with any deterioration in hearing (Karlsmose et al, 2000). In the present study, we looked for an interaction with noise exposure (Table 4), and found that smoking was not a risk factor in the group with the strongest exposure to occupational noise. This could indicate that if the occupational exposure to noise is intensive, the injury due to noise saturates at a certain level independently of smoking habits.

Disruption of cochlear blood flow (ischemia) and reduction in available oxygen levels have been suggested as fundamental mechanisms that are responsible loss of hearing and may potentiate the effects of noise (Fechter, 1995; Fechter, Chen & Rao, 2002). This hypothesis has been supported by experimental studies in laboratory animals, where carbon monoxide exposure comparable to levels induced by smoking potentiates the effects of noise exposure. While the effects of noise exposure partially recovered, the hearing loss caused by the combined exposure did not (Chen & Fechter, 1999), indicating that carbon monoxide is exerting its effects by disrupting the regenerative processes following acute noise exposures. Factors such as heart dysfunction (Susmano & Rosenbush, 1988), hypertension (Hong & Kim, 2001; Starck, Toppila & Pyykkö, 1999; Pyykkö, Pekkarinen & Starck, 1987; Talbot et al, 1985) and serum cholesterol (Toppila, Pyykkö & Starck, 2001; Axelsson & Lindgren, 1985) have also been identified as risk factors of hearing loss, which underscores the possible importance of vascular diseases in the development of hearing impairment.

Height
As height was related to age in the study population (see Methods), the apparent strong associations between height and hearing loss incidence and prevalence weaken in the multiple logistic regressions where all variables are controlled for simultaneously. This was also the case if we treated age as a continuous variable. The regression analyses show that that the relation between short stature and prevalence was only borderline significant and that there was no relation between adult body height and incidence of hearing loss. We also found that the association was stronger among females than among males, and very strong among employees born 1950 and before. One explanation could be that in populations where adult height is primarily caused by the genetic potential, the association between adult height and hearing loss is weak. Regarding gender, it has been found that genetic factors seem to affect male height more than female height (Pietilainen et al, 2002) indicating that female height to a greater extent reflects environmental factors. This might explain why the odds for prevalence of hearing loss were higher among females than among males. Regarding birth year, we suspect that adult body height is caused by the environment to a larger degree among people born before 1950 than among people born after 1950. In another Scandinavian population, the Finnish, it has been shown that heritability of height increased in the first half of the 20th century and leveled off after World War II (Silventoinen et al, 2000). It should be noted that malnutrition did not affect birth height among people born in Denmark during the Second World War (Angell-Andersen et al, 2004). In addition, the older employees studied in this paper were relatively unselected as we excluded employees with an age ($>$55 years) close to the average age of retirement which in Denmark is around 60. Among people aged over 55 years in Denmark, employees are markedly healthier and report better hearing than people who have left the labor market (data not shown).

It has been found in a number of studies that the combination of impaired fetal growth and subsequent compensatory increased rapid growth in childhood has been associated with high risks in adulthood not only for stroke but also for elevated blood pressure and type 2 diabetes (Barker, 2002). Nonetheless, low birth weight is associated with short adult stature (Loos et al, 2001; Pietilainen et al, 2001). Low birth weight can be seen as a marker of impaired fetal growth. Barker suggests that the growth pattern may also affect the number of cells in the liver (Barker, 2002), and so impaired fetal growth may also directly affect the development of the inner ear. This is supported by a number of studies relating low birth weight to hearing loss (Nafstad et al, 2002; Vohr et al, 2000; Van Naarden & Decoufle, 1999; Sutton and Rowe, 1997). Alternatively, low birth weight may lead to hearing loss partly because it leads to vascular disease.

Conclusion

Our study shows that smoking is independently associated with incidence of hearing loss. This indicates that smoking deteriorates hearing. Short stature was only associated with prevalence of hearing loss in subpopulations where variations in body height reflect environmental conditions prior to adulthood. Both results – more convincingly the association between smoking and elevated incidence of hearing loss – add to the evidence on a number of pathways leading to hearing loss.

The study also demonstrates that it is possible to use questionnaires in follow-up studies exploring possible risk factors for hearing loss. We suggest that the possible associations found in the present study should be analyzed in other cohort studies containing data on hearing, smoking and height.

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