

Risk of cancer for arc welders in the Federal Republic of Germany: results of a second follow up (1983-8)

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Abstract

An extended follow up of 1221 chromium and nickel exposed welders in the Federal Republic of Germany confirmed an increased relative risk of 1.6 for all cancers compared with an internal reference group of 1694 turners. In an external comparison an excess of deaths from malignant tumours compared with that expected from the national mortality rates was found (standardised mortality ratio (SMR) = 109), which was clearly related to both time since first exposure and duration of exposure. Mortality from lung cancer was increased among welders (SMR = 113) but also among turners (SMR = 108). The difference remained when the subgroups were compared according to smoking information. A large excess of mesothelioma as a cause of death could be attributed to exposure to asbestos. The significantly increased SMR seen for urogenital tumours and "other or unspecified tumours" showed, however, an inverse relation with time since first exposure. This and other inconsistencies in the analysis by type of welding do not permit conclusive statements. Thus a further extension of follow up seems warranted.

A historical follow up study was conducted among 1221 arc welders exposed to fumes containing chromium and nickel and an internal reference group of 1694 turners to identify health hazards resulting from exposure to welding fumes containing nickel and chromium. In the initial follow up an increased risk of cancer was found in comparison with the turners as well as with the general population of the Federal Republic of Germany. This could not, however, be identified with respect to specific cancer sites or to types of welding.¹ The data of this first follow up were incorporated into the European study

on stainless steel, mild steel, and shipyard welders carried out in 1987-9 by the International Agency for Research on Cancer (IARC) in which a statistically significant excess was detected for mortality from lung cancer.² Our present paper outlines the findings of a second follow up of the German cohort study until March 1988 after an extension of about six years. Our study has the advantage of providing information on individual exposure conditions as well as smoking state as exposure data were collected individually. The European study used estimated average exposure data based on company levels but they also included secular changes. With respect to the peculiarities of the German stainless steel processing factories, however, the differences between the activities of the stainless steel welders within a company were of greater relevance than the secular changes in the working processes.

Materials and methods

MATERIALS

As previously described,¹ welders and turners who had worked for at least six months during the years 1950-70 were identified from 25 factories of the metal processing industry by using personnel files of the respective factories. Descriptions of the exposure conditions were obtained for each person individually by consultation with the superiors and the foremen. Thus data were collected on the main type of welding used, working conditions, average daily welding time, and smoking state.

The vital status of the study subjects at the end of the first follow up in 1982 served as the starting point for the present follow up. Actual vital status was determined from the population registers. For persons whose death and date of death were established in this way, cause of death was requested from the local health offices of the last home address. A copy of the death certificate was made available to the centre if the nearest relative of the deceased gave written consent. A persistent problem is, therefore, the response rate of the relatives in giving written consent. Although compliance is high at the moment, it seems to depend on external factors—for example, current public discussion on data protection.

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The welders who were still actively employed at the end of the initial follow up were traced simultaneously by direct enquiry at the respective companies. Information on exposure, working conditions, type of welding, and smoking behaviour was updated by the respective foremen and superiors using a structured questionnaire. Due to the closure of two companies and the refusal of two others, such information was not available for 34 and 27 welders respectively. During the process of updating, eight of the original 1221 welders and six of the 1694 turners were found to be misclassified and had to be excluded. Thus the updated cohorts comprise 1213 welders and 1688 turners.

The inquiry of the companies showed that 289 welders were still active, 187 were still employed but no longer as welders and 69 had left the companies either due to change of employment or retirement (table 1). The employment state of the turners was not updated. By March 1988, 153 welders and 288 turners had died, and 152 and 274 death certificates respectively were obtained. Seven welders (0.6%) and 18 turners (1.1%) were lost to follow up and eight (0.7%) and 11 (0.7%) respectively had gone abroad. A total of 31 122 person-years of observation were accumulated in the welder's group and 51 157 in the turner's group (table 1).

An inspection of deaths by calendar periods showed a deficit of deaths before 1968 compared with those expected. In the international study, the data of the period before 1968 were excluded from the analysis. So far, no explanation can be given for this deficit of deaths. Since the technical examination certificates were kept meticulously, welders who died before 1968 could not have been selectively excluded from the study cohort. Also no excess of persons was lost to follow up in this period and a selection effect is unlikely given the standard follow up procedure. Therefore, the present analysis was carried out using the complete data set.

METHODS

Maximum likelihood estimates of the rate ratios (RRs) and 95% confidence intervals (95% CI) were calculated for the internal comparison between the welders and the control group.³ Because the age structures of two cohorts were slightly different (see table 2 in Becker *et al.*)¹ age was stratified into four age groups—namely, younger than 35, 35–54, 55–69, and 70 or older. The analysis was carried out using the computer package EPAS⁴ according to the methods described in Rothman and Boice.⁵ For the external comparison standardised mortality ratios (SMRs) were calculated using the official mortality statistics of the Federal Republic of Germany that were made available to the Centre for compiling the German Cancer Atlas.⁶ Secular changes of mortality were taken into account by using mortality of the general

Table 1 Results of the second follow up

	Welders	Turners
No of persons alive	1045	1371
Still employed:		
As welder/turner	289	—
Not as welder/turner	187	—
Retired	569	—
Deceased	153	288
Death certificate available	152	274
Death certificate not available	1	14
Lost to follow up	7	18
Moved abroad	8	11
Total	1213	1688
Person-years	31 122	51 157

population for four calendar periods: 1950–67, 68–73, 74–78, and 79–85 for calculating the expected values and 95% CIs were calculated assuming a Poisson distribution.⁷

Results

As expected the major causes of death among both the welders and the turners were diseases of the cardiovascular system, followed by all malignant neoplasms, then the unnatural causes (accidents, poisonings, and violence) and diseases of the digestive system (table 2). Other causes contributed less than 10 cases each. The unusually large number of 18 deaths with ill defined causes among the turners was due to deaths for which death certificates were not available being assigned to this group. Of the malignant neoplasms, cancers of the respiratory system were most common (including three mesothelioma deaths), with cancers of the digestive system ranking second (table 3).

INTERNAL COMPARISON

Mortalities from all causes and from cardiovascular diseases were similar among welders and turners (table 2). A significant excess of malignant neoplasms was found, however (RR = 1.6). Within the group of malignant neoplasms the RR for cancers of other and unspecified sites that include tumours of the brain and of the thyroid (RR = 3.5) was significantly increased (table 3). A non-significant raised risk was found for cancers of the urogenital system (RR = 2.5), especially for prostate (RR = 5.2) and bladder tumours (RR = 10.2).

The RRs remained essentially unchanged after adjustment for the confounding factor of smoking and are not presented here. Instead, an evaluation of the effect of smoking in comparison with the general population is presented.

EXTERNAL COMPARISON

Compared with the general population of the Federal

Table 2 Cause specific deaths among welders and turners and RRs for the total period of observation

Cause of death	No of deaths		RR (95% CI)
	Welders	Turners	
Infectious diseases (000-136)*	3	4	1.5 (0.3-6.7)
Malignant neoplasms (140-209)	48	62	1.6 (1.1-2.3)
Neoplasms of unspecified nature (210-239)	0	4	— (0.1-9.1)
Endocrine, metabolic, and immunity disorders (240-279)	1	3	0.7 (0.1-7.0)
Blood and blood forming organs (280-289)	0	2	— (0.1-18.7)
Mental disorders (290-315)	1	2	0.8 (0.1-8.3)
Nervous system and sensory organs (320-389)	0	2	— (0.1-17.5)
Circulatory system (390-458)	54	129	0.9 (0.6-1.2)
Respiratory system (460-519)	7	8	1.9 (0.7-5.3)
Digestive system (520-577)	12	21	1.1 (0.5-2.2)
Genitourinary system (580-607)	2	5	0.7 (0.1-3.8)
Skin and subcutaneous tissue (680-709)	0	1	— (0.0-52.4)
Symptoms, signs and ill defined conditions (780-796)	4	18	0.5 (0.2-1.4)
Accidents, poisonings, violence (800-999)	20	27	1.2 (0.7-2.1)
All causes (000-999)	153	288	1.0 (0.9-1.3)

*International Classification of Diseases, 8th revision.

Republic of Germany the significantly lower total mortality among both welders and turners (SMR = 79 and 76) indicated a strong healthy worker effect (table 4). The SMR for cardiovascular diseases showed a reduction of the same magnitude

among the welders but slightly less among the turners (SMR = 89). By contrast, the SMR for malignant neoplasms was appreciably higher among welders (SMR = 109) whereas it remained significantly below 100 among turners (SMR = 71).

Table 3 Site specific deaths from cancer among welders and turners and RRs for the total period of observation

Cancer site	No of deaths		RR (95% CI)
	Welders	Turners	
Lip, oral cavity and pharynx (140-149)	0	1	— (0.0-62.7)
Digestive organs and peritoneum (150-159)	12	18	1.3 (0.6-2.6)
Oesophagus (150)	2	0	— (0.0- > 999)
Stomach (151)	3	10	0.6 (0.2-2.3)
Colon (153)	1	1	2.4 (0.1-39.3)
Rectum (154)	2	1	4.0 (0.4-45.8)
Liver (155)	0	1	— (0.0-62.7)
Gallbladder (156)	0	1	— (0.0- > 999)
Pancreas (157)	3	4	1.2 (0.3-5.3)
Peritoneum (158)	1	0	— (0.0- > 999)
Respiratory and intrathoracic organs (160-165)	17	26	1.4 (0.8-2.6)
Trachea, bronchus, lung (162)	14	26	1.2 (0.6-2.2)
Other and ill defined sites (163)	3	0	— (0.0- > 999)
Bone, connective tissue, skin and breast (170-175)	2	1	3.1 (0.3-34.2)
Bone and articular cartilage (170)	1	0	— (0.0- > 999)
Skin (172)	1	1	1.6 (0.1-26.5)
Genitourinary organs (180-189)	7	6	2.5 (0.8-7.4)
Prostate (185)	2	1	5.2 (0.5-58.3)
Penis and other male genital organs (187)	1	0	— (0.0- > 999)
Bladder (188)	4	2	4.5 (0.8-24.9)
Kidney and other unspecified urinary organs (189)	0	3	— (0.1-10.5)
Other and unspecified sites (190-199)	9	5	3.5 (1.2-10.5)
Brain (191)	2	1	2.7 (0.2-29.3)
Other and unspecified parts of nervous system (192)	1	0	— (0.0- > 999)
Thyroid gland (193)	1	0	— (0.0- > 999)
Other endocrine glands and related structures (194)	1	0	— (0.0- > 999)
Secondary neoplasms of respiratory and digestive system (197)	1	2	1.0 (0.1-10.7)
Malignant neoplasms without specified site (199)	3	2	3.2 (0.5-19.8)
Lymphatic and haematopoietic tissue (200-208)	1	5	0.4 (0.0-3.6)
Lymphosarcoma and reticular sarcoma (200)	0	1	— (0.0-64.2)
Multiple myeloma (203)	1	0	— (0.0- > 999)
Lymphoid leukaemia (204)	0	2	— (0.0-21.2)
Myeloid leukaemia (205)	0	1	— (0.0-62.7)
Other and unspecified leukaemia (207)	0	1	— (0.0-62.7)
Malignant neoplasms (140-208)	48	62	1.6 (1.1-2.3)

Table 4 Mortality analysis (SMR) for welders and turners for the total period of observation: all causes of death

Cause of death	Welders		Turners	
	Obs/exp	SMR (95% CI)	Obs/exp	SMR (95% CI)
Infectious diseases (001-136)	3/2.8	106 (34-327)	4/5.8	68 (26-182)
Malignant neoplasms (140-209)	48/44.1	109 (82-144)	62/86.4	71 (56-92)
Benign neoplasms (210-239)	0/2	0 —	4/3.8	106 (40-282)
Endocrine, metabolic, and immunity disorders, blood and blood forming organs (240-289)	1/3.5	28 (4-201)	5/7.4	68 (28-163)
Mental disorders (290-315)	1/2.9	35 (5-245)	2/4.2	48 (12-190)
Nervous system and sensory organs (320-389)	0/3	0 —	2/5.5	36 (9-145)
Circulatory system (390-458)	54/68.8	79 (60-103)	129/145.3	89 (75-106)
Respiratory system (460-519)	7/9.5	74 (35-155)	8/22.1	36 (18-72)
Digestive system (520-579)	12/16.7	72 (41-127)	21/28.9	73 (47-111)
Genitourinary system (580-629)	2/2.7	75 (19-302)	5/6.1	81 (34-195)
Skin and subcutaneous tissue (680-738)	0/0.5	0 —	1/1	100 (14-689)
Symptoms, signs and ill defined conditions (780-796)	5/5.6	90 (37-215)	18/10.2	177 (112-281)
Accidents, poisonings, violence (800-999)	20/29.8	67 (43-104)	27/51.35	53 (36-77)
All causes (001-999)	153/192.3	79 (67-93)	288/378.6	76 (68-85)

Also, a significantly lower SMR was seen among the turners for diseases of the respiratory system (SMR = 36), and for accidents, poisoning, and violence (SMR = 53).

Within the group of malignant neoplasms, significant excesses were found among welders for deaths from mesothelioma (SMR = 961), bladder

cancer (SMR = 304), and cancers of other and ill defined sites (SMR = 214). The significantly raised SMRs for cancers of other genital organs among welders and for ill defined leukaemia among turners were due to only one case each. A significant deficit of cancers of the digestive system was also seen for the turners (SMR = 60). Mortality from lung cancer

Table 5 Mortality analysis (SMR) for welders and turners for the total period of observation: malignant neoplasms

Cancer site	Welders		Turners	
	Obs/exp	SMR (95% CI)	Obs/exp	SMR (95% CI)
Lip, oral cavity and pharynx (140-149)	0/1.3	0 (—)	1/2.0	50 (7-663)
Digestive organs and peritoneum (150-159)	12/14.9	80 (46-142)	18/30	60 (38-95)
Oesophagus (150)	2/1.1	178 (44-711)	0/2.0	0 (—)
Stomach (151)	3/5.3	57 (18-177)	10/11.3	89 (48-164)
Colon (153)	1/3	33 (5-237)	1/5.9	17 (2-120)
Rectum (154)	2/1.9	105 (26-422)	1/3.9	26 (4-183)
Liver (155)	0/0.4	0 (—)	1/0.8	122 (17-867)
Gallbladder (156)	0/0.6	0 (—)	1/1.2	86 (12-612)
Pancreas (157)	3/2.0	150 (49-470)	4/3.7	108 (41-288)
Peritoneum (158)	1/0.2	637 (89-999)	0/0.3	0 (—)
Respiratory and intrathoracic organs (160-165)	17/13.3	128 (80-206)	26/25.8	101 (69-148)
Trachea, bronchus, lung (162)	14/12.4	113 (67-191)	26/24.1	108 (7-15)
Other and ill-defined sites (163)	3/0.3	961 (310-999)	0/0.6	0 (—)
Bone, connective tissue, skin and breast (170-175)	2/1.4	148 (37-590)	1/2.3	43 (6-305)
Bone and articular cartilage (170)	1/0.2	479 (68-999)	0/0.4	0 (—)
Skin (172)	1/0.6	159 (22-999)	1/1.0	100 (14-704)
Genitourinary organs (180-189)	7/5.4	129 (62-271)	6/11.9	51 (23-112)
Prostate (185)	2/2.0	100 (26-410)	1/5.0	20 (3-142)
Penis and other male genital organs (187)	1/0.1	1431 (202-999)	0/0.1	0 (—)
Bladder (188)	4/1.3	304 (114-810)	2/2.9	68 (17-273)
Kidney and other unspecified urinary organs (189)	0/1.5	0 (—)	3/2.6	114 (37-352)
Other and unspecified sites (190-199)	9/4.2	214 (111-410)	5/7.8	64 (27-153)
Brain, other and unspecified parts of the nervous system (191, 192)	3/1.1	278 (90-860)	1/1.7	58 (8-409)
Thyroid gland (193)	1/0.2	580 (82-999)	0/0.3	0 (—)
Other endocrine glands and related structures (194)	1/0.1	1587 (24- > 999)	0/0.1	0 (—)
Secondary neoplasms of respiratory and digestive system (197)	1/12	81 (11-572)	2/2.4	82 (21-328)
Malignant neoplasms without specified site (199)	3/2	150 (48-439)	2/3.7	54 (13-215)
Lymphatic and haematopoietic tissue (200-208)	1/3.4	30 (4-210)	5/6.2	80 (34-193)
Lymphosarcoma and reticular sarcoma (200)	0/0.4	0 (—)	1/0.7	136 (19-964)
Multiple myeloma (203)	1/0.3	293 (41-999)	0/0.7	0 (—)
Lymphoid leukaemia (204)	0/0.4	0 (—)	2/0.7	270 (68-999)
Myeloid leukaemia (205)	0/0.7	0 (—)	1/1.2	83 (12-588)
Other and unspecified leukaemia (207)	0/0.04	0 (—)	1/0.04	2346 (30- > 999)
Malignant neoplasms (140-208)	48/44.1	109 (82-144)	62/86.4	72 (56-92)

was higher than expected from overall mortality among both welders and turners, with SMR of 113 and 108 respectively, although this was not statistically significant (table 5).

SMOKING

To study the effect of smoking, mortality analyses were performed separately for cohort members who were definitely smokers or non-smokers. The total number of subjects is lower than that seen in the previous tables as persons with unknown smoking habits and ex-smokers are excluded. For smoking welders and smoking turners total mortality and mortality from cardiovascular diseases were comparable with those expected from the general population—that is, the healthy worker effect almost disappeared in this subgroup (table 6). Among welders the excess mortality from malignant neoplasms reached statistical significance, the SMR of 144 being considerably higher than that for total mortality and also clearly higher than that for cancer mortality in the group of turners (SMR = 89). The SMRs for several individual tumour sites (cancer of the lung (SMR = 179), mesothelioma (SMR = 1098), and bladder cancer (SMR = 389)) in the group of smoking welders were significantly higher than before. Other significantly raised SMRs, for peritoneal tumours, bone tumours and thyroid tumours, were only based on one observed case each. By contrast, the increased mortality from lung cancer remained non-significant among smoking turners (SMR = 134).

For non-smoking welders and non-smoking turners significantly reduced total mortality (SMR = 59 and SMR = 43 respectively) and mortality from cardiovascular diseases (SMR = 56 and SMR 65) were found (table 7). For all cancers, however, the deficit was significant only for the turners (SMR = 24) but not for welders (SMR = 79).

Although now based on only one case, the SMR for mesothelioma among non-smoking welders was statistically significant (table 7). Among non-smoking turners no mortalities from specific cancer sites were significantly increased but mortalities from cancers of the digestive system (SMR = 10) and of the respiratory system (SMR = 23) were significantly reduced, especially for cancer of the lung (SMR = 25). Although the SMR for lung cancer among non-smoking welders was of the same magnitude as among non-smoking turners, it was not statistically significant because of smaller numbers of observed and expected cases.

TIME SINCE FIRST EXPOSURE

Total mortality among welders increased from significantly low values in the first two decades after first exposure (SMR = 35 and SMR = 71) to magnitudes of about 100 in the last two decades (SMR = 101 and SMR = 92) (table 8). For both total cancer mortality and mortality from lung cancer the SMR increased steadily although the individual SMRs were not significant. An inverse relation was seen between observation time since first exposure and mortality from cancers of the urogenital system and cancers of other and unspecified sites, in which the highest SMR was found for an observation time of less than 10 years.

Analogous evaluations for turners showed a similar increase in total mortality and total cancer mortality with observation time but with generally lower SMRs. For lung cancer, a weak upward trend was also apparent, with an SMR reaching 149 in the last decade. Mortality from cancers of the urogenital system and of "other and unspecified sites" also showed a downward trend similar to that of the welders although only two data points were available for each.

Table 6 Mortality analysis for smoking welders and turners for the total period of observation

Cause of death	Smoking welders		Smoking turners	
	Obs/exp	SMR (CL)	Obs/exp	SMR (CL)
Malignant neoplasms (140-209)	37/25.8	144 (104-198)	42/47.4	89 (66-120)
Lip, oral cavity and pharynx (140-149)	0/0.8	— (—)	1/1.0	102 (14-723)
Digestive organs and peritoneum (150-159)	8/8.7	92 (46-183)	12/168	72 (41-126)
Respiratory and intrathoracic organs (160-163)	15/7.8	192 (116-319)	1/14.3	126 (80-200)
Trachea, bronchus, lung (162)	13/7.3	179 (104-308)	18/13.4	134 (85-213)
Other and ill defined sites (163)	2/0.2	1098 (275->999)	0/0.3	— (—)
Bone, connective tissue, skin and breast (170-175)	2/0.8	255 (64->999)	0/1.2	— (—)
Genitourinary organs (180-189)	3/3.1	95 (31-296)	3/6.7	45 (15-139)
Other and unspecified sites (190-199)	8/2.5	326 (163-651)	5/4.2	11 (49-285)
Lymphatic and haematopoietic tissue (200-208)	1/2.0	51 (7-362)	3/3.2	93 (30-287)
Circulatory system (390-458)	36/40.0	90 (65-125)	75/81.5	92 (73-115)
Respiratory system (460-519)	4/5.5	73 (27-193)	7/12.6	56 (27-117)
Accidents, poisonings, violence (800-999)	13/17.0	77 (44-132)	14/24.0	8 (35-99)
All causes (001-999)	106/111.5	95 (79-115)	180/204.5	88 (76-102)

Table 7 Mortality analysis for non-smoking welders and turners for the total period of observation

Cause of death	Non-smoking welders		Non-smoking turners	
	Obs/exp	SMR (CL)	Obs/exp	SMR (CL)
Malignant neoplasms (140-209)	11/14.0	79 (43-142)	7/29.1	24 (12-50)
Lip, oral cavity and pharynx (140-149)	0/0.4	— (—)	0/0.7	— (—)
Digestive organs and peritoneum (150-159)	4/4.7	85 (32-227)	1/101	10 (1-71)
Respiratory and intrathoracic organs (160-163)	2/4.2	48 (12-190)	2/8.6	23 (6-93)
Trachea, bronchus, lung (162)	1/3.9	26 (4-182)	2/8.0	25 (6-99)
Other and ill defined sites (163)	1/0.1	997 (141-> 999)	0/0.2	— (—)
Bone, connective tissue, skin and breast (170-175)	0/0.4	— (—)	1/0.8	125 (18-890)
Genitourinary organs (180-189)	4/1.7	237 (89-633)	1/4.0	25 (4-175)
Other and unspecified sites (190-199)	1/1.4	74 (10-525)	0/2.6	— (—)
Lymphatic and haematopoietic tissue (200-208)	0/1.1	— (—)	2/2.1	94 (24-376)
Circulatory system (390-458)	12/21.5	56 (32-99)	32/49.2	65 (46-92)
Respiratory system (460-519)	2/2.9	69 (17-275)	0/7.4	— (—)
Accidents, poisonings, violence (800-999)	6/10.0	60 (27-133)	5/18.1	28 (12-66)
All causes (001-999)	36/61.4	59 (42-81)	55/129	43 (33-56)

DURATION OF EXPOSURE

The simultaneous consideration of time since first exposure and duration of exposure (that is, employment as a stainless steel welder) showed that the increasing trend of SMR with time since first exposure for all cancers consisted of two different aspects: firstly, increasing SMR with increasing time since first exposure that, however, levelled off after 30

years for each category of duration of exposure, and secondly, a continuously increasing trend of SMR with increasing duration of exposure for categories of time since first exposure, in particular for 30 or more years (table 9). Unfortunately, this effect was not so evident for lung cancer since the data were more scattered due to small numbers in the respective cells (for details see Becker *et al*⁸). The average daily

Table 8 Mortality analysis by time since first exposure for welders and turners

Time since first exposure (y)	Welders		Turners	
	Obs/exp	SMR (95% CI)	Obs/exp	SMR (95% CI)
All causes (000-999):				
≤ 9	11/31.5	35 (19-62)	17/42.2	40 (25-65)
10-19	42/59.0	71 (53-96)	58/75	77 (60-100)
20-29	65/64.5	101 (79-129)	94/112	84 (68-103)
≥ 30	34/37.0	92 (66-129)	119/149	80 (67-96)
Total	152/192.3	79 (67-93)	288/378.6	76 (68-85)
Malignant neoplasms (140-208):				
≤ 9	2/4.8	42 (10-166)	1/6.3	16 (2-113)
10-19	11/13.1	84 (47-150)	11/15.5	71 (39-128)
20-29	23/16.5	139 (93-209)	18/27.2	66 (42-105)
≥ 30	12/9.7	123 (70-212)	32/37.3	86 (61-121)
Total	48/44.1	109 (82-144)	62/86.4	71 (56-92)
Trachea, bronchus, lung (162):				
≤ 9	0/1.0	— (—)	0/1.3	— (—)
10-19	2/3.6	56 (14-224)	4/4.2	96 (36-256)
20-29	7/4.9	142 (68-299)	6/7.9	76 (34-169)
≥ 30	5/2.9	172 (72-414)	16/10.7	149 (91-244)
Total	14/12.4	113 (67-191)	26/24.1	108 (73-158)
Genitourinary organs (180-189):				
≤ 9	2/0.5	387 (97-> 999)	0/0.7	(—) (—)
10-19	0/1.3	— (—)	0/1.8	— (—)
20-29	3/2.0	147 (48-457)	5/3.4	147 (61-354)
≥ 30	2/1.5	131 (33-525)	1/6.0	17 (2-118)
Total	7/5.4	129 (62-271)	6/11.9	51 (23-112)
Other and ill defined sites (190-199):				
≤ 9	0/0.6	— (—)	0/0.7	— (—)
10-19	4/1.3	297 (112-791)	2/1.6	128 (32-511)
20-29	4/1.5	268 (101-714)	0/2.5	— (—)
≥ 30	1/0.8	124 (18-883)	3/3.1	97 (31-302)
Total	9/4.2	214 (111-410)	5/7.8	64 (27-153)

Table 9 Mortality analysis among welders regarding time since first exposure and duration of exposure: malignant neoplasms

Duration of exposure (y)	Time since first exposure (y)			
	0-9	10-19	20-29	≥30
<1	0/0.1	0/0.3	0/0.1	0/0.0
1-9	2/4.7 43 13-154	6/4.2 143 64-318	5/3.8 132 55-316	1/1.2 81 11-574
10-19	—	5/8.6 58 26-136	10/5.1 197 106-366	2/2.0 101 25-405
20-29	—	—	8/7.5 107 55-210	4/3.3 120 45-319
≥30	—	—	—	5/3.2 157 65-378
Total	2/4.8 42 10-166	11/13.1 84 47-150	23/16.5 139 93-209	12/9.7 123 70-212

duration of welding time with different welding techniques was estimated to provide a semiquantitative measure of intensity of exposure. Cause specific mortality by categories of welding time, however, did not show a dose-effect relation; the highest SMR was consistently seen for the lowest category of daily welding time regardless of type of welding.⁹

WELDING TECHNIQUES

A separate analysis was performed for three subgroups of welders according to the primary welding techniques used—that is, persons who were exclusively engaged in coated electrode welding, those who worked only with different types of gas

shielded welding (MIG/MAG and WIG), and persons who worked with both welding techniques. A few welders who used other welding techniques were excluded from this analysis. An increasing trend in mortality occurred from all causes, all cancers, and lung cancer with increasing observation time since first exposure for all types of welding although a levelling off in the last observation period was sometimes seen (table 10). In general the SMRs were higher for those exposed exclusively either to coated electrodes or to gas shielded electrodes. A higher risk for persons who worked exclusively with coated electrodes compared with those who worked exclusively with gas shielded electrodes could not be established; however, the estimates of the SMRs of the former group were based on larger numbers of observed and expected cases and should thus be considered more reliable. The finding of slightly lower SMRs among those persons who had mixed exposure to both types of welding techniques was also inconsistent although again numbers were few.

Discussion

The analysis of the study of German welders after an extended follow up period shows a small but significant increase in mortality from malignant neoplasms among welders. Compared with the internal reference group of turners, the RR of 1.6 is statistically significant, but, lower than the RR of 2.4 found in the previous evaluation.¹ The SMR of 109 for malignant neoplasms is also appreciably higher than that for total mortality among welders (SMR = 79) and for malignant neoplasms among the turners (SMR = 71). The differences between the groups are

Table 10 Mortality analysis by time since first exposure for the subgroups of welders using coated electrodes, or MIG/MAG and WIG, or both techniques

Time since first exposure (y)	Only coated electrodes		Coated electrodes and MIG/MAG, WIG		Only MIG/MAG, WIG	
	Obs/exp	SMR (95% CI)	Obs/exp	SMR (95% CI)	Obs/exp	SMR (95% CI)
All causes (000-999):						
≤9	7/12.6	56 (27-117)	2/11.8	17 (4-68)	2/5.4	37 (9-149)
10-19	20/23.4	85 (55-132)	13/22.1	59 (34-102)	7/9.7	72 (34-151)
20-29	38/30.1	125 (92-174)	21/22.4	94 (61-144)	6/7.4	81 (36-180)
≥30	20/18.2	110 (71-170)	6/13.5	45 (20-99)	4/3.1	129 (48-343)
Total	85/84.3	101 (82-125)	42/69.8	60 (45-82)	19/25.6	74 (47-116)
Malignant neoplasms: (140-208)						
≤9	1/2.2	46 (6-325)	1/1.6	62 (9-437)	0/0.7	— (—)
10-19	4/5.4	75 (28-199)	3/4.8	63 (20-194)	4/2.1	188 (71-502)
20-29	14/7.7	182 (108-307)	7/5.8	120 (57-251)	2/1.9	105 (26-419)
≥30	6/4.7	127 (57-283)	2/3.7	55 (14-218)	2/0.8	247 (62-988)
Total	25/20.0	125 (85-185)	13/15.9	82 (47-141)	8/5.6	144 (72-288)
Trachea, bronchus, lung: (162)						
≤9	0/0.5	— (—)	0/0.3	— (—)	0/0.1	— (—)
10-19	1/1.5	65 (9-461)	0/1.3	— (—)	1/0.6	180 (25-199)
20-29	6/2.3	259 (116-577)	1/1.8	57 (8-404)	0/0.6	— (—)
≥30	2/1.4	145 (36-580)	1/1.1	88 (12-627)	1/0.2	428 (60->999)
Total	9/5.7	157 (82-301)	2/4.4	45 (11-180)	2/1.5	137 (34-546)

also slightly reduced with respect to the first evaluation where the SMR was 97 for malignant neoplasms among welders compared with 65.6 for total mortality and 53 for all malignant neoplasms among turners.

By contrast with the initial follow up no difference occurs in mortality from lung cancer between the welders and the turners. The SMRs of 113 and 108 respectively, however, for the two groups are both raised compared with the SMR for total mortality. The deficit of lung cancer among turners in the previous follow up was attributable to cases of lung cancer that occurred among persons lost to follow up, some of whom were relocated during this follow up. Some specific cancer sites show significantly increased risk in this evaluation—namely, mesothelioma, bladder cancer, and cancers of “other and unspecified sites”.

Smoking habits of working populations have often been found to be different from that of the general population. Emmerling *et al*⁹ found the percentage of smokers among welders (56%) to be higher than that of the total German population (40%).¹⁰ Using the crude information with regard to smoking in the two cohorts, 57% of the welders were reported as smokers by contrast with only 41% among turners. The adjustment for smoking in the internal comparison of the welders and the turners did not result in any essential change in the RRs, indicating that smoking was not likely to be the explanation of the difference. More interesting were the results from the independent comparison of smokers and non-smokers with the total population, which showed that SMRs for malignant neoplasms, mesothelioma, bladder tumours, and cancers of “other and unspecified sites” were raised among welders, regardless of smoking state. A clear difference in the SMRs for these causes of death between smoking welders and smoking turners as well as non-smoking welders and non-smoking turners suggest that smoking is not a major cause of the differences in risk between the two cohorts. Recently published studies showing higher mutagenicity in the urine of carcinogen exposed workers independent of smoking support this observation.¹¹⁻¹³

Regarding lung cancer, although the SMR was high in both smoking welders and turners and low in non-smoking welders and turners, a difference between the smoking subgroups was evident, even though the number of observed cases was small for the non-smokers. This finding agrees with the results of research on occupational risk factors, which has repeatedly indicated an increased risk for lung cancer among steel workers and steel welders.^{14,15} A large pooled case-control study on occupational risk factors for lung cancer showed, after shipyard workers, the highest statistically confirmed odds ratios (ORs) for lung cancer in steel production workers (OR =

1.2, 95% CI = 1.0-1.6) and among welders (OR 1.2, 95% CI = 1.0-1.8).¹⁶ Smoking was not the explanation of the excess risk. A similar study carried out in two areas of northern Italy showed raised ORs for welders as well as for metal workers.¹⁷ The smoking adjusted risk for lung cancer for welders was about 2.9 (95% CI = 0.9-9.8). Smoking did not appear to exert a substantial confounding effect.

Further support for an occupational cause of the raised cancer risk among welders is provided by the increase in SMR with increasing time since first exposure and with increasing duration of exposure. For lung cancer, however, an upward trend of SMR with time since first exposure is evident not only among the welders but also among the turners. On the other hand, the inverse relation with time since first exposure for cancers of the urogenital system and cancers of “other or unspecified sites” suggests that previous exposures may be associated with the raised mortality. Although theoretical considerations show that even with continued exposure, the RR need not necessarily continuously increase or may even decrease after a certain period;¹⁸ the unclear pattern of SMR in these two groups of tumour sites and the lack of previous observations of an association with the welding occupation do not allow a conclusive explanation for the increased risk found.

The previous analysis gave an indication of a higher risk of cancer among welders working with coated electrodes. As these produce more fumes containing chromium and nickel than gas shielded electrodes, a higher exposure to chromium nickel fumes could be causally related to higher risks of cancer among these welders. In the present analysis, however, raised SMRs for malignant neoplasms and for lung cancer were found for both subgroups of welders using coated electrodes only and those using gas-shielded electrodes only. The estimates for the first group are based on larger numbers of expected and observed cases, but the unexpected finding of generally lower SMRs in the subgroup of welders with mixed exposures, although based on low numbers of observed and expected cases, renders it difficult to attribute an increased risk of cancer to a particular type of welding technique.

The consistent finding of an excess of mesothelioma among the welders compared with expected values from the general population and the occurrence of three cases of mesothelioma in comparison with no case among the control group of turners suggest a real difference between the two groups. No doubt exposure to asbestos occurs during welding and although it may account totally for the observed cases of mesothelioma and possibly for some of the cases of lung cancer, it cannot be considered as the dominating factor for an occupational risk among welders at large. Especially, it appears impracticable to quantify the contribution

of exposure to asbestos to lung cancer from the risk of mesothelioma because the risk for lung cancer and for mesothelioma varies with the type of asbestos, and this is unknown.

In summary, our second follow up confirms an occupation related health hazard among stainless steel welders. An increased mortality was found for total cancer and for special sites, such as tumours of the urogenital organs and "tumours of other or unspecified sites." The indication of a dose-response effect for mortality from total cancer by duration of exposure (table 9) provides further evidence for the notion of a real health hazard among welders. On the other hand, neither daily amount of exposure time nor intensity of exposure (type of welding) fit into a consistent pattern of dose-response effects. A further inconsistently is the inverse time course of the SMR for urogenital tumours with increasing time since first exposure. The risk for lung cancer was not significantly raised, but increased with duration of exposure. Mortality from lung cancer only weakly increased after the removal of the effects of smoking and a part of the increase must clearly be attributed to exposure to asbestos. Hence the increased risk of lung cancer identified in this study is smaller than in the international study. Thus, the second follow up of the study of German welders does not yet allow final conclusions. The small excess of lung cancer among turners deserves further study. Therefore, a new follow up study will be carried out after a further five year period of observation.

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