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Original Contribution

Exposure to Farm Crops, Livestock, and Farm Tasks and Risk of Glioma

The Upper Midwest Health Study

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Some studies of brain cancer have found an excess risk for farmers. The National Institute for Occupational Safety and Health previously found no increased glioma risk for ever (vs. never) being exposed to pesticides on a farm among 798 cases and 1,175 population-based controls (adult (ages 18–80 years) nonmetropolitan residents of Iowa, Michigan, Minnesota, and Wisconsin). For this analysis (1995–1998), 288 cases and 474 controls (or their proxies) who had lived on farms at age 18 years or after were asked about exposure to crops, livestock, and farm tasks. Logistic regression was used to calculate odds ratios adjusted for age, age group, sex, state, and education. Never immediately washing up (adjusted odds ratio (OR) = 3.08, 95% confidence interval (CI): 1.78, 5.34) or changing clothes (OR = 2.84, 95% CI: 1.04, 7.78) after applying pesticides was associated with increased glioma risk. Living on a farm on which corn, oats, soybeans, or hogs were raised was associated with decreased risk (corn—OR = 0.37, 95% CI: 0.20, 0.69; oats—OR = 0.63, 95% CI: 0.40, 1.00; soybeans—OR = 0.69, 95% CI: 0.48, 0.98; hogs—OR = 0.63, 95% CI: 0.43, 0.93). Negative associations may be due to chance or a "healthy farmer" effect. Farmers' increased risk of glioma may be due to work practices, other activities, or an inverse association with allergies (reported by other investigators).

agriculture; animals, domestic; brain neoplasms; case-control studies; crops, agricultural; glioma; occupational exposure; pesticides

Abbreviations: CI, confidence interval; OR, odds ratio.

Although overall mortality is lower among farmers than in the general population, several studies have found an excess risk of brain cancer for farmers ranging from 1.5 times to 5.0 times that of the general population or other occupational groups studied (1–6). Other studies have not found an increased risk (7–9). In 1995, the National Institute for Occupational Safety and Health initiated the Upper Midwest Health Study, a population-based case-control study of brain cancer risk in a nonmetropolitan midwestern US population. In previous analyses of data from this study, we did not find increased risk for self-reported ever exposure (vs. never exposure) to a number of individual pesticides and classes of pesticides (10, 11). However, agricultural workers are exposed to a number of other agents hypothesized to increase the risk of brain cancer, including nitrates, solvents, and viruses. The selection of crops and livestock raised on a farm and the manner in which farm tasks (such as cleaning of tools) are conducted determine whether some of these agents are present or absent.

In this study, we evaluated associations between reported exposure to crops, livestock, and farm tasks and glioma among nonmetropolitan residents of 4 Upper Midwestern states. Our primary hypothesis was that some of these exposures are associated with the increased glioma risk found in some studies of farmers. We also planned to determine how all participants, those who had ever lived or worked on

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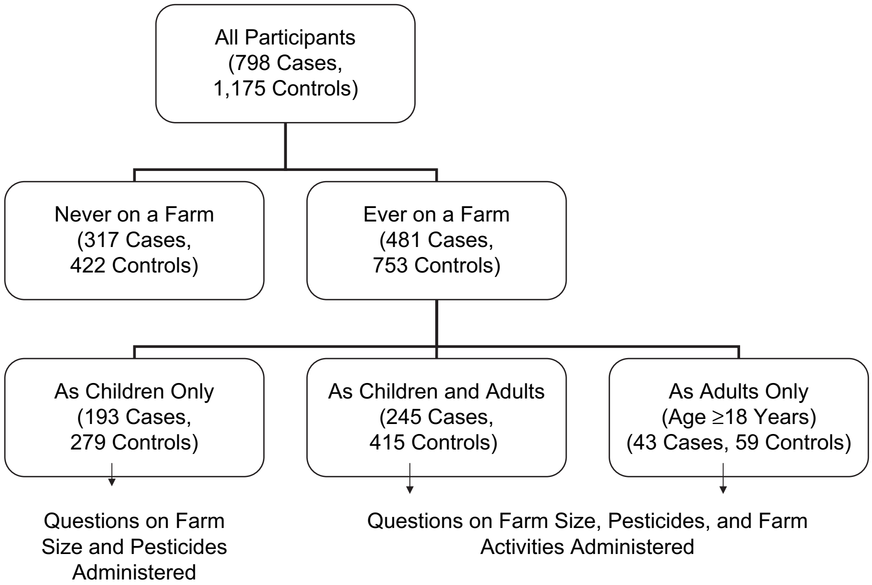

Figure 1. Distribution of participants by farm experience, Upper Midwest Health Study, 1995–1998. Among persons who had ever lived or worked on a farm, 39 were missing data on the farm-related questions.

a farm (ever farmers), and those who had lived or worked on a farm at age 18 years or older (adult farmers) differed in age and sex distribution, how ever farmers and adult farmers differed in responses to questions about farm size and pesticides, and whether responses to the questions on farm activities differed significantly between cases and controls.

MATERIALS AND METHODS

The study sample and design have been described previously (12). The 4 study states—Iowa, Michigan, Minnesota, and Wisconsin—have large farm populations and higher-than-average brain cancer incidence. Using the glioma distribution by sex and age at diagnosis (in 10-year age groups) during a 3-year period (1989–1992) in the 4 study states, we selected potential controls (2:1 to projected number of cases) who resided in eligible nonmetropolitan counties on January 1, 1995, from state driver's license records (for persons aged 18–64 years) or from the Health Care Financing Administration's Medicare data tapes (for persons aged 65–80 years). Sampling randomly within sex-age strata, we chose a pool of potential controls as the case enrollment period began. Cases and controls reporting a prior malignancy other than glioma (6.4% of cases, 20.6% of controls) were not excluded.

We focused on histologically confirmed primary intracranial gliomas, rather than all brain neoplasms, to reduce heterogeneity among the case participants. A brain glioma was defined as a neoplasm with an *International Classification of Diseases for Oncology*, Second Edition, code of 938–948 (13). Cases diagnosed between January 1, 1995, and January 31, 1997, were identified through participating medical facilities and neurosurgeons' offices. Case ascertainment, assessed by comparison with respective state tumor registry ascertainment for eligible counties, was 78% overall (12). Physician consent was obtained before contacting cases or their next of kin. Cases interviewed in person ($n = 438$) were interviewed an average of 196 days after diagnosis; proxy case interviews ($n = 360$) occurred an average of 420 days after diagnosis (partly because we waited some time after a case death before approaching family members). Among cases, 59% had a diagnosis of glioblastoma multiforme (equivalent to stage 4 glioma); 22% had astrocytoma; 11% had oligodendroglioma; and 8% had other glioma subtypes.

Potential participants were sent a letter of invitation, followed by a telephone call to request participation. Informed consent was solicited from all potential participants. Among eligible potential participants, 70.4% of 1,669 controls and 91.5% of 872 cases (or their next of kin) agreed to participate (12). This study was approved by the National Institute for Occupational Safety and Health Human Subjects Review Board and the review boards of all participating institutions.

The questionnaire, modified from one developed by the National Cancer Institute (14), included a farm section. Only participants who had lived or worked on a farm at or after the age of 18 years were asked about farm activities other than pesticide use, although the questions were not restricted to activities engaged in during adulthood. The farm questions covered a wide range. Respondents were asked whether corn, spring wheat, winter wheat, milo (grain sorghum), sorghum, oats, barley, rye, flax, rice, hay, or soybeans were grown. Details about acreage (converted herein to hectarage; 100 acres equals approximately 40 hectares), years grown, and farm storage were solicited for crops grown while the participant was on the farm. Questions

Table 1. Demographic Characteristics of Glioma Cases and Controls by Farm Experience,[a] Upper Midwest Health Study, 1995–1998[b]

	Including Proxy Respondents				Excluding Proxy Respondents			
	Cases		Controls		Cases		Controls	
	No. or Mean (SD)	%	No. or Mean (SD)	%	No. or Mean (SD)	%	No. or Mean (SD)	%
All participants	798	40	1,175	60	438	28	1,141	72
Never lived on a farm	317	43	422	57	191	32	412	68
Male/female, no.	162/155		208/214		93/98		202/210	
Age in 1993, years	48.7 (17)		50.2 (16)		42.5 (14)		49.8 (15)*	
Ever lived/worked on a farm	481	39	753	61	247	25	729	75
Male/female, no.	295/186		440/313		149/98		423/306	
Hectarage	89 (239)		87 (206)		110 (254)		88 (209)	
No. of years spent on farm	23.5 (20)		26.0 (21)*		21.6 (19)		25.8 (21)*	
Age in 1993, years	53.8 (15)		57.0 (14)*		47.7 (15)		56.7 (14)*	
Lived on farm only as a child (age <18 years)	193	41	279	59	99	27	268	73
Male/female, no.	124/69		155/124		59/40		146/122	
Hectarage	38 (53)		52 (90)*		43 (51)		54 (92)	
No. of years spent on farm	9.7 (7)		8.7 (7)		9.1 (7)		8.7 (7)	
Age in 1993, years	50.6 (16)		53.8 (16)*		44.6 (15)		53.4 (16)*	
Pesticides used/not used on farm	57/136		96/183		40/59		96/172	
Lived on farm as both a child and an adult	245	37	415	63	127	24	404	76
Male/female, no.	155/90		262/153		83/44		254/150	
Hectarage	106 (215)		108 (261)		150 (289)		109 (265)	
No. of years spent on farm	35.8 (20)		38.3 (20)		33.0 (18)		38.0 (20)	
Age in 1993, years	56.5 (15)		59.0 (13)*		50.3 (15)		58.6 (13)*	
Pesticides used/not used on farm	187/58		349/66		101/26		341/63	
Lived on farm only as an adult (age ≥18 years)	43	42	59	58	21	27	57	73
Male/female, no.	16/27		23/36		7/14		23/34	
Hectarage	219 (581)		102 (118)		203 (464)		102 (119)	
No. of years spent on farm	13.0 (13)		20.7 (14)*		10.4 (9)		19.5 (13)*	
Age in 1993, years	52.0 (12)		58.7 (12)*		46.2 (10)		58.2 (12)	
Pesticides used/not used on farm	27/16		41/18		14/7		40/17	

Abbreviation: SD, standard deviation.

* $P < 0.05$ (t test for cases vs. controls).

[a] None, any, childhood only, both childhood and adulthood, or adulthood only.

[b] All data are mean values with standard deviations in parentheses unless otherwise specified.

followed about the use of fertilizers and the crops they had been used on; selected livestock raised on the farm and/or slaughtered by the participant; and common farm tasks the participant had performed: cleaning the barn; using, fueling, or repairing farm equipment; and maintaining farm structures.

We hypothesized that engaging in farm activities would increase the risk of intracranial brain gliomas, by increasing exposure to agents used in those activities. In this study, all estimates of association were adjusted through modeling. All analyses used SAS 9.1 software (15). We fitted unconditional multiple logistic regression models in order to obtain maximum-likelihood parameter estimates (16). In these models, we evaluated the effects of multiple exposures and confounders simultaneously. The models included age, sex (because farm tasks often vary by sex (17)), state of residence (because differences in climate and terrain influence the choice of crops and livestock (18)), age group (because it was a matching factor for control selection), and education (as a surrogate for socioeconomic status). Models were fitted

Table 2. Relation Between Exposure to Farm Crops and Risk of Glioma Among Participants Living or Working on a Farm At or After Age 18 Years, Upper Midwest Health Study, 1995–1998[a]

	Including Proxy Respondents						Excluding Proxy Respondents					
	Cases (*n* = 288)[b]		Controls (*n* = 474)[b]		OR[c]	95% CI	Cases (*n* = 148)[b]		Controls (*n* = 461)[b]		OR[c]	95% CI
	No. or Mean (SD)	%	No. or Mean (SD)	%			No. or Mean (SD)	%	No. or Mean (SD)	%		
Corn												
Corn grown on farm, ever/all	224/247	91	427/444	96	0.37*	0.20, 0.69	116/130	89	416/434	96	0.38*	0.17, 0.84
Corn hectarage	47 (57)		45 (63)		1.00	0.998, 1.001	53 (65)		45 (64)		1.00	0.998, 1.001
Age when corn was first grown on farm[d], years	7.7 (11.5)		9.2 (13.3)		0.99	0.98, 1.00	7.4 (10.7)		9.3 (13.4)		0.99	0.97, 1.01
No. of years corn was grown	30.4 (20.5)		30.0 (18.9)		1.00	0.99, 1.01	27.6 (18.7)		29.7 (18.9)		1.00	0.99, 1.01
Corn stored on farm, ever/all	204/217	94	392/424	92	1.35	0.68, 2.67	104/114	91	381/413	92	0.98	0.45, 2.13
Spring wheat												
Spring wheat grown on farm, ever/all	51/238	21	86/437	20	1.18	0.78, 1.79	25/129	19	83/425	20	1.25	0.72, 2.17
Spring wheat hectarage	35 (104)		35 (87)		1.00	0.998, 1.002	57 (137)		36 (88)		1.00	0.999, 1.002
Age when spring wheat was first grown on farm[d], years	11.0 (15.9)		19.1 (17.7)		0.97*	0.95, 1.00	7.3 (10.4)		19.3 (17.7)		—[e]	—[e]
No. of years spring wheat was grown	18.3 (15.9)		13.8 (14.3)		1.01	0.99, 1.03	18.0 (15.8)		13.8 (14.5)		1.02	1.00, 1.05
Spring wheat stored on farm, ever/all	34/45	76	59/83	71	1.21	0.49, 2.95	18/23	78	57/80	71	—[e]	—[e]
Winter wheat												
Winter wheat grown on farm, ever/all	62/237	26	109/434	25	0.89	0.59, 1.35	34/130	26	108/422	26	0.95	0.57, 1.60
Winter wheat hectarage	14 (14)		14 (22)		1.00	0.99, 1.003	15 (16)		14 (22)		1.00	0.99, 1.01
Age when winter wheat was first grown on farm[d], years	12.1 (12.7)		16.8 (18.3)		0.98	0.95, 1.01	14.9 (12.8)		17.0 (18.3)		0.99	0.96, 1.03
No. of years winter wheat was grown	19.6 (21.1)		13.7 (14.0)		1.01	0.99, 1.02	14.6 (16.1)		13.6 (14.0)		1.00	0.98, 1.03
Winter wheat stored on farm, ever/all	30/56	54	60/104	58	0.76	0.39, 1.48	19/31	61	60/103	58	1.26	0.50, 3.17
Oats												
Oats grown on farm, ever/all	199/239	83	393/442	89	0.63*	0.40, 1.00	104/130	80	381/430	89	0.71	0.40, 1.26
Oat hectarage	14 (13)		13 (13)		0.998	0.99, 1.00	16 (16)		13 (13)		1.00	0.99, 1.01
Age when oats were first grown on farm[d], years	7.8 (11.4)		8.9 (13.6)		0.99	0.98, 1.01	6.8 (10.4)		8.9 (13.5)		0.99	0.97, 1.01
No. of years oats were grown	27.4 (19.7)		26.6 (17.3)		1.00	0.99, 1.01	24.8 (18.0)		26.4 (17.1)		1.00	0.99, 1.01
Oats stored on farm, ever/all	179/194	92	359/383	94	0.90	0.44, 1.85	94/103	91	348/372	94	1.11	0.46, 2.71

Table continues

for all controls versus all cases and all controls versus cases with glioblastoma multiforme (the largest glioma subtype). We also performed separate analyses for men and women.

We decided a priori not to make a statistical adjustment for the type of respondent. Instead we performed separate analyses using data only from participants, excluding proxy responses, and using data from participants and proxies combined, including proxy responses (19). Interviews with participants (some including their relatives as well) were conducted for 239 (71%) of 336 cases not diagnosed with glioblastoma, 199 (43%) of 462 cases with glioblastoma, and 1,141 (97%) of 1,175 controls, respectively. In the tables, we report results for both inclusion and exclusion of proxy responses. In the text, unless noted, we report only results including proxy responses.

Our primary analysis of farm activities excluded nonfarmers and persons who had lived on a farm only as children; they were not asked the questions about farm activities. We repeated our analyses including nonfarmers, under the assumption that they had never been exposed to any farm crops, livestock, or farm tasks. Persons who had lived on a farm only as children could not be presumed either to have been or not to have been exposed to farm crops, livestock, or farm tasks and therefore were excluded.

Table 2. Continued

	Including Proxy Respondents						Excluding Proxy Respondents					
	Cases (n = 288)[b]		Controls (n = 474)[b]		OR[c]	95% CI	Cases (n = 148)[b]		Controls (n = 461)[b]		OR[c]	95% CI
	No. or Mean (SD)	%	No. or Mean (SD)	%			No. or Mean (SD)	%	No. or Mean (SD)	%		
Barley												
Barley grown on farm, ever/all	60/231	26	110/435	25	1.07	0.73, 1.58	39/128	30	110/423	26	1.70*	1.04, 2.79
Barley hectarage	14 (17)		18 (40)		1.00	0.99, 1.00	18 (20)		18 (40)		1.00	0.997, 1.01
Age when barley was first grown on farm[d], years	17.6 (17.2)		12.1 (13.0)		1.03*	1.00, 1.06	17.8 (17.0)		12.1 (13.0)		1.03	1.00, 1.07
No. of years barley was grown	12.6 (11.2)		13.0 (11.5)		1.00	0.98, 1.02	11.7 (10.6)		13.0 (11.5)		1.02	0.99, 1.05
Barley stored on farm, ever/all	44/57	77	84/103	82	0.93	0.37, 2.33	27/37	73	84/103	82	0.87	0.31, 2.50
Hay												
Hay grown on farm, ever/all	233/247	94	421/445	95	0.84	0.45, 1.59	123/132	93	409/433	94	1.03	0.45, 2.37
Hay hectarage	22 (35)		19 (20)		1.001	0.998, 1.003	25 (44)		19 (20)		1.00	0.999, 1.01
Age when hay was first grown on farm[d], years	8.1 (11.7)		8.9 (13.2)		0.99	0.98, 1.01	8.8 (11.9)		8.8 (13.1)		1.00	0.98, 1.02
No. of years hay was grown	28.3 (19.7)		28.8 (18.1)		1.00	0.99, 1.01	25.4 (18.2)		28.6 (18.0)		1.01	0.99, 1.02
Hay stored on farm, ever/all	222/227	98	402/413	97	1.23	0.41, 3.71	118/121	98	390/401	97	1.51	0.39, 5.79
Soybeans												
Soybeans grown on farm, ever/all	124/239	52	270/442	61	0.69*	0.48, 0.98	65/130	50	264/430	61	0.58*	0.37, 0.91
Soybean hectarage	45 (74)		34 (53)		1.00	0.999, 1.002	49 (89)		34 (53)		1.00	0.998, 1.002
Age when soybeans were first grown on farm[d], years	18.4 (17.2)		21.7 (15.6)		0.99	0.97, 1.01	16.3 (15.5)		21.6 (15.5)		0.99	0.97, 1.01
No. of years soybeans were grown	22.0 (17.5)		20.5 (16.1)		1.00	0.99, 1.01	18.5 (13.3)		20.2 (15.7)		0.99	0.97, 1.00
Soybeans stored on farm, ever/all	68/117	58	144/259	56	1.07	0.67, 1.68	33/63	52	141/254	56	0.66	0.35, 1.23
Other crops grown on farm, ever/all[e]												
Sorghum	38/232	16	71/438	16	1.02	0.66, 1.58	19/128	15	70/426	16	0.85	0.48, 1.51
Milo[f]	13/237	6	24/432	6	1.06	0.52, 2.17	4/128	3	23/421	6	0.73	0.24, 2.26
Rice	2/240	<1	2/443	<1	1.66	0.22, 12.4	1/130	<1	2/431	<1	1.15	0.10, 13.7
Rye	33/230	14	81/439	18	0.66	0.42, 1.05	19/128	15	81/427	19	0.77	0.43, 1.39
Flax	25/238	11	60/440	14	0.91	0.54, 1.57	15/129	12	60/428	14	1.26	0.63, 2.51

Abbreviations: CI, confidence interval; OR, odds ratio; SD, standard deviation.

* $P < 0.05$.

[a] All data are mean values with standard deviations in parentheses unless otherwise specified.

[b] Numbers of definite positive or negative responses varied by question. Respondents who answered "no" to the general question about a crop were not asked about acreage, storage, or years grown.

[c] Adjusted for sex, age, 10-year age group, education, and state. Nonfarmers, persons who had lived on farms only as children, and persons who gave "don't know" responses were excluded. For continuous variables, odds ratios are for a 1-unit change.

[d] For nongrowers, "age when first grown" (unlike acreage and years, both equal to 0) could not be estimated. Analyses included only those participants who had ever lived on a farm where that crop was grown.

[e] The numbers of participants on whose farms these crops were grown were too small to make further analyses meaningful.

[f] Milo is grain sorghum.

RESULTS

The Upper Midwest Health Study included 798 cases and 1,175 controls (438 cases and 1,141 controls interviewed in person; the rest, by proxy). Figure 1 shows the distributions of cases and controls by farm residence/workplace and age. Thirty-six percent of cases and 41% of controls had been born on a farm ($\chi^2 = 5.54$, $P < 0.02$).

Controls were older than cases. Participants who had ever lived or worked on a farm were older than those who had never lived/worked on a farm, and ever-farm controls had spent significantly more time on the farm than had ever-farm

Table 3. Relation Between Exposure to Livestock and Risk of Glioma Among Participants Living or Working on a Farm At or After Age 18 Years, Upper Midwest Health Study, 1995–1998[a]

	Including Proxy Respondents						Excluding Proxy Respondents					
	Cases (n = 288)[b]		Controls (n = 474)[b]		OR[c]	95% CI	Cases (n = 148)[b]		Controls (n = 461)[b]		OR[c]	95% CI
	No. or Mean (SD)	%	No. or Mean (SD)	%			No. or Mean (SD)	%	No. or Mean (SD)	%		
Dairy cows												
Dairy cows raised on farm, ever/all	207/257	81	390/459	85	0.75	0.49, 1.16	102/135	76	380/448	85	0.87	0.51, 1.48
No. of dairy cows on farm	27 (28)		32 (132)		1.00	0.99, 1.01	30 (35)		26 (27)		1.00	0.99, 1.01
Age when dairy cows were first raised on farm[d], years	6.4 (10.1)		6.4 (10.9)		1.00	0.98, 1.02	5.8 (8.3)		6.5 (10.9)		1.00	0.97, 1.02
No. of years dairy cows were raised	24.0 (16.0)		24.5 (15.6)		1.00	0.99, 1.02	22.6 (15.1)		24.1 (15.4)		1.01	0.99, 1.03
Milking machine used on farm, ever/all	111/125	89	208/230	90	0.88	0.41, 1.89	60/70	86	203/225	90	1.25	0.49, 3.20
Age when milking machine was first used on farm[e], years	17.9 (10.7)		17.1 (10.3)		1.03	1.00, 1.06	13.3 (8.7)		16.9 (10.3)		0.99	0.95, 1.03
Cleaning a cow barn, ever/all[f]	85/104	82	165/199	83	0.56	0.27, 1.17	46/54	85	161/194	83	1.01	0.36, 2.86
Time spent cleaning cow barn, hours/week	21.2 (13.7)		20.5 (15.2)		1.00	0.98, 1.02	22.1 (14.2)		20.7 (15.3)		1.01	0.98, 1.03
Other cattle												
Other cattle raised on farm, ever/all	189/254	74	354/457	77	0.82	0.56, 1.19	103/135	76	347/446	78	1.00	0.60, 1.65
No. of other cattle on farm	64 (175)		61 (122)		1.00	1.00, 1.00	60 (107)		61 (123)		1.00	1.00, 1.00
Age when other cattle were first raised on farm[d], years	8.6 (12.4)		11.6 (15.2)		0.99	0.97, 1.00	8.0 (11.6)		11.3 (14.9)		0.98	0.97, 1.00
No. of years other cattle were raised	26.6 (17.4)		25.9 (17.8)		1.01	1.00, 1.02	25.2 (16.7)		25.9 (17.9)		1.01	1.00, 1.03
Butchering cattle, ever/all	65/156	42	140/312	45	0.86	0.56, 1.33	36/83	43	136/301	45	1.07	0.61, 1.85
No. of cattle butchered per year	2.3 (4.0)		6.1 (53.0)		1.00	0.98, 1.01	1.8 (1.4)		6.2 (53.6)		0.99	0.90, 1.09
Age when first butchered cattle[d], years	16.9 (10.6)		16.1 (9.1)		1.01	0.97, 1.04	18.4 (10.4)		16.4 (9.0)		1.03	0.99, 1.08
No. of years cattle were butchered	27.8 (18.2)		19.6 (11.8)		1.02	0.96, 1.08	25.9 (19.7)		19.8 (11.9)		—[g]	—[g]
Manure												
Removing barn manure, ever/all	135/197	69	304/415	73	0.63	0.38, 1.04	77/108	71	297/402	74	0.82	0.43, 1.56
Time spent in manure removal, hours/week	8.6 (8.5)		8.3 (6.4)		1.00	0.98, 1.03	8.9 (9.4)		8.1 (6.1)		1.02	0.99, 1.06
Method of manure removal, ever/all												
Machine	9/171	5	24/333	7			4/94	4	23/326	7		
Hand tools	100/171	58	217/333	65			57/94	61	212/326	65		
Both	62/171	36	92/333	28			33/94	35	91/326	28		
Applying manure to fields, ever/all	145/239	61	276/437	63	0.88	0.56, 1.39	78/130	60	268/424	63	0.83	0.47, 1.47

Table continues

cases. Approximately 40% of ever farmers were female, but among those who had only lived or worked on a farm as an adult, over 60% were female. Participants who had lived on farms only as children recalled living on significantly smaller farms (a mean hectarage of 46 (standard deviation, 78) vs. a mean hectarage of 113 (standard deviation, 269) for all other ever farmers; $P < 0.0001$). Participants who had first lived on a farm as infants or children were at non-statistically significantly reduced risk compared with all other participants (for infants, adjusted odds ratio (OR) = 0.90, 95% confidence interval (CI): 0.70, 1.15; for children, OR = 0.97, 95% CI: 0.62, 1.51). Those who had first lived or worked on a farm as adolescents were at non-statistically significantly increased risk compared with all other participants (OR = 1.33, 95% CI: 0.76, 2.34).

Table 1 shows data on farm size and years of living or working on a farm for cases and controls, including and excluding proxy responses. Participants who had lived on farms only as children had spent less time on the farm, were younger in 1993, and were less likely to recall pesticides having been used than the other farmer groups (childhood + adulthood and adulthood only).

Table 2 compares case and control responses regarding exposure to grain crops. Except for barley and rye, cases had

Table 3. Continued

	Including Proxy Respondents						Excluding Proxy Respondents					
	Cases (n = 288)[b]		Controls (n = 474)[b]		OR[c]	95% CI	Cases (n = 148)[b]		Controls (n = 461)[b]		OR[c]	95% CI
	No. or Mean (SD)	%	No. or Mean (SD)	%			No. or Mean (SD)	%	No. or Mean (SD)	%		
Chickens												
Chickens raised on farm, ever/all	211/260	81	395/459	86	0.73	0.48, 1.12	102/135	76	385/448	86	0.80	0.47, 1.34
No. of chickens on farm	190 (748)		209 (515)		1.00	1.00, 1.00	141 (260)		210 (521)		1.00	1.00, 1.00
Confinement of chickens in chicken house, ever/all[f]	74/129	57	132/257	51	1.07	0.68, 1.68	30/63	48	129/247	52	0.72	0.39, 1.34
Age when chickens were first raised on farm[d], years	7.0 (11.2)		7.5 (12.2)		1.00	0.98, 1.01	6.6 (10.7)		7.5 (12.3)		1.00	0.98, 1.02
No. of years chickens were raised	21.5 (15.3)		21.8 (14.9)		1.00	0.99, 1.02	18.6 (12.3)		21.5 (14.7)		1.00	0.98, 1.02
Killing chickens, ever/all	141/162	87	286/312	92	0.57	0.32, 1.03	72/83	87	276/301	92	0.72	0.32, 1.60
No. of chickens killed per year	63 (184)		55 (130)		1.00	1.00, 1.00	77 (245)		54 (131)		1.00	1.00, 1.00
Age when first killed chickens[d], years	13.4 (8.9)		16.2 (9.5)		0.97*	0.94, 0.99	13.0 (8.2)		16.3 (9.4)		0.97	0.93, 1.00
No. of years chickens were killed	19.7 (12.8)		19.0 (15.5)		1.01	0.94, 1.05	20.6 (13.7)		19.0 (15.6)		1.02	0.98, 1.06
Hogs												
Hogs raised on farm, ever/all	190/254	75	378/456	83	0.63*	0.43, 0.93	102/135	76	369/446	83	0.86	0.52, 1.43
No. of hogs on farm	138 (255)		128 (217)		1.00	0.99, 1.001	172 (312)		130 (219)		1.00	1.00, 1.00
Confinement of hogs in hog house, ever/all	77/187	41	145/376	39	1.03	0.70, 1.52	51/101	51	144/367	39	1.45	0.90, 2.35
Age when hogs were first raised on farm[d], years	9.3 (12.9)		8.6 (12.7)		1.01	0.99, 1.02	9.7 (12.9)		8.5 (12.6)		1.01	0.99, 1.03
No. of years hogs were raised	22.0 (17.8)		23.5 (17.2)		1.00	0.99, 1.01	19.3 (15.5)		23.2 (17.1)		0.99	0.98, 1.01
Butchering hogs, ever/all	67/159	42	152/311	49	0.71	0.47, 1.09	36/83	43	148/300	49	0.87	0.50, 1.51
No. of hogs butchered per year	2.7 (4.8)		2.7 (2.7)		0.98	0.89, 1.07	2.1 (1.5)		2.7 (2.6)		0.84	0.66, 1.08
Age when first butchered hogs[d], years	14.3 (9.9)		16.2 (8.6)		0.97	0.94, 1.01	17.2 (10.7)		16.5 (8.5)		1.02	0.98, 1.08
No. of years hogs were butchered	24.2 (16.5)		14.4 (8.9)		1.15*	1.01, 1.33	23.5 (20.5)		14.8 (8.7)		—[g]	—[g]

Abbreviations: CI, confidence interval; OR, odds ratio; SD, standard deviation.

* $P < 0.05$.

[a] All data are mean values with standard deviations in parentheses unless otherwise specified.

[b] Numbers of definite positive or negative responses varied by question. Respondents who answered "no" to the general question about exposure to an animal were not asked about numbers of animals or years raised.

[c] Adjusted for sex, age, 10-year age group, education, and state. Nonfarmers, persons who had lived on farms only as children, and persons who gave "don't know" responses were excluded. For continuous variables, odds ratios are for a 1-unit change.

[d] On farms not raising/killing these animals, "age when first raised/killed" (unlike number of animals and years, both equal to 0) could not be estimated. Analyses included only those participants who had ever lived on a farm where these animals were raised/killed.

[e] On farms without milking machines, "age when first used on farm" could not be estimated. Analyses included only those participants who had ever lived on a farm with a milking machine.

[f] Only asked of participants whose farms had more than 19 dairy cows or more than 99 chickens, respectively.

[g] The numbers of participants on whose farms these animals were raised were too small to make further analyses meaningful.

generally been younger than or the same age as controls when a crop had first been grown on the farm. Percentages of respondents reporting a specific crop were similar in analyses including and excluding proxies. Cases and controls were equally likely (96% of those growing grain) to have stored grain on the farm, but controls had stored more types of grain (3.7 types vs. 3.4 types; $P < 0.05$). Growing corn, oats, or soybeans was associated with a statistically significantly decreased risk of glioma (for corn, adjusted OR = 0.37, 95% CI: 0.20, 0.69; for oats, OR = 0.63, 95% CI: 0.40, 1.00; and for soybeans, OR = 0.69, 95% CI: 0.48, 0.98). Among persons who had lived or worked on a farm where barley was grown, the older the participant had been when barley was first grown, the greater was his or her glioma risk (per year of age, OR = 1.03, 95% CI: 1.00, 1.06). Conversely, among persons who had lived or worked on a farm where spring wheat was grown, the older the participant had been when spring wheat was first grown

Table 4. Relation Between Exposure to Farm Tasks Not Related to Crops or Livestock and Risk of Glioma Among Participants Living or Working on a Farm At or After Age 18 Years, Upper Midwest Health Study, 1995–1998[a]

	Including Proxy Respondents						Excluding Proxy Respondents					
	Cases (*n* = 288)[b]		Controls (*n* = 474)[b]		OR[c]	95% CI	Cases (*n* = 148)[b]		Controls (*n* = 461)[b]		OR[c]	95% CI
	No. or Mean (SD)	%	No. or Mean (SD)	%			No. or Mean (SD)	%	No. or Mean (SD)	%		
Pesticides												
Never using mask or gloves while applying pesticides, yes/all	108/146	74	206/288	72	1.13	0.69, 1.84	53/83	64	202/282	72	0.74	0.42, 1.32
Never washing face and hands immediately after applying pesticides, yes/all	96/118	81	148/247	60	3.08*	1.78, 5.34	46/64	72	144/241	60	1.72	0.93, 3.31
Never changing clothes immediately after applying pesticides, yes/all	112/117	96	219/248	88	2.84*	1.04, 7.78	59/64	92	214/242	88	1.45	0.50, 4.17
Laundering pesticide-applicator clothes, ever/all	68/206	33	137/396	35	0.76	0.47, 1.22	36/111	32	135/388	35	0.68	0.38, 1.24
Never wearing gloves while laundering and never running washing machine through an empty cycle afterward, yes/all	57/62	92	115/132	87	1.68	0.56, 5.01	35/37	95	114/130	88	2.77	0.54, 14.1
Storage of pesticides in house, ever/all	16/189	8	21/370	6	1.70	0.85, 3.40	8/104	8	21/361	6	1.71	0.71, 4.16
Nitrogen fertilizers												
Nitrogen fertilizers used on farm, ever/all	164/214	77	307/410	75	1.03	0.68, 1.55	94/120	78	299/398	75	0.78	0.45, 1.35
Personal application of nitrogen fertilizers, ever/all												
To corn	69/152	45	141/300	47	1.46	0.85, 2.48	38/87	44	138/292	47	1.43	0.75, 2.73
To milo	7/33	21	4/65	6	5.58*	1.24, 25.2	4/18	22	4/64	6	—[d]	—[d]
To wheat	18/63	29	30/120	25	1.77	0.81, 3.87	12/38	32	30/118	25	2.25	0.82, 6.12
Farm equipment												
Repairing farm equipment, ever/all	125/252	50	248/453	55	0.66	0.39, 1.09	72/133	54	242/441	55	0.81	0.41, 1.59
Time spent repairing farm equipment, hours/month	13.7 (25.8)		11.2 (18.4)		1.00	0.99, 1.01	15.9 (31.5)		11.3 (18.6)		1.00	0.99, 1.01
Getting hydraulic fluid on skin, ever/all	85/123	69	161/246	65	1.15	0.70, 1.90	51/74	69	159/241	66	0.95	0.51, 1.78
Getting hydraulic fluid on skin, hours/month	3.2 (10.9)		4.0 (13.2)		1.00	0.97, 1.02	3.2 (13.3)		4.0 (13.3)		0.99	0.96, 1.02
Years of using hydraulic fluid equipment	23.8 (13.5)		23.7 (14.5)		1.01	0.99, 1.03	20.9 (8.9)		23.5 (14.5)		1.01	0.98, 1.03
Driving farm equipment, ever/all	186/251	74	343/454	78	0.79	0.51, 1.22	109/135	81	345/442	78	1.11	0.61, 2.00
Years of driving farm equipment	23.7 (17.7)		24.4 (18.5)		1.00	0.99, 1.01	20.5 (16.7)		24.4 (18.4)		1.00	0.98, 1.01
Time spent driving farm equipment, days/year	181 (137)		180 (132)		1.00	0.999, 1.002	175 (133)		180 (133)		1.00	0.998, 1.002
Driving farm equipment for ≥8 hours, days/year	90 (84)		77 (71)		1.003	1.00, 1.01	83 (79)		77 (71)		1.00	0.998, 1.01
Driving the same amount in all years, yes/all	104/156	67	203/304	67			53/89	60	199/298	67		
Driving diesel equipment, ever/all	102/157	65	193/308	65	1.05	0.67, 1.64	65/92	71	190/301	63	0.99	0.58, 1.76
Years of driving diesel equipment	16.5 (10.1)		16.0 (10.5)		1.02	0.91, 1.04	14.2 (9.0)		15.9 (10.5)		1.00	0.97, 1.03
Fueling farm equipment, ever/all	140/153	92	271/302	90	1.45	0.62, 3.39	84/90	93	265/296	90	1.74	0.57, 5.35
Fueling farm equipment, times/week	3.9 (3.5)		4.4 (3.7)		0.97	0.91, 1.04	4.1 (3.7)		4.4 (3.8)		1.00	0.92, 1.09
Driving equipment with a closed cab, ever/all	67/161	42	140/305	46	0.78	0.51, 1.19	40/93	43	136/299	45	0.73	0.43, 1.23
Percentage of time spent driving equipment with a closed cab	52 (37)		53 (35)		1.00	0.99, 1.01	54 (37)		52 (35)		—[d]	—[d]
Use of a comfort cover, ever/all	73/187	39	156/359	43	0.85	0.57, 1.29	40/109	37	152/350	43	0.73	0.44, 1.23

Table continues

Table 4. Continued

	Including Proxy Respondents						Excluding Proxy Respondents					
	Cases (n = 288)[b]		Controls (n = 474)[b]		OR[c]	95% CI	Cases (n = 148)[b]		Controls (n = 461)[b]		OR[c]	95% CI
	No. or Mean (SD)	%	No. or Mean (SD)	%			No. or Mean (SD)	%	No. or Mean (SD)	%		
Farm structure maintenance												
Welding, ever/all	64/255	25	111/454	24	1.08	0.71, 1.64	40/133	30	108/441	24	1.22	0.72, 2.08
Time spent welding, hours/month[e]	3.5 (5.9)		2.8 (4.6)		1.01	0.94, 1.08	3.6 (5.5)		2.8 (4.7)		1.00	0.93, 1.09
Soldering, ever/all	34/249	14	60/455	13	1.09	0.67, 1.77	21/134	16	57/442	13	1.22	0.67, 2.23
Time spent soldering, hours/month	1.3 (3.4)		1.1 (1.8)		1.01	0.85, 1.21	0.7 (1.0)		1.1 (1.8)		0.81	0.52, 1.27
Using a solvent to clean hands, ever/all	139/241	58	255/443	58	1.15	0.79, 1.68	78/131	60	250/431	58	1.11	0.69, 1.79
Using a solvent for hand cleaning, times/month	3.7 (5.9)		4.7 (7.3)		0.97	0.94, 1.01	4.1 (6.0)		4.7 (7.3)		0.98	0.93, 1.02
Using a solvent to clean tools, ever/all	116/246	47	216/451	48	1.07	0.71, 1.63	62/132	47	212/440	48	0.89	0.42, 1.52
Using a solvent for tool cleaning, hours/month	3.5 (7.1)		3.6 (7.5)		1.00	0.97, 1.03	3.4 (5.9)		3.6 (7.6)		0.98	0.94, 1.03
Method of applying solvent, ever/all												
Wiping[f]	40/117	34	64/221	29	1.28	0.78, 2.08	22/66	33	63/217	29	1.34	0.71, 2.50
Brushing	71/117	61	140/221	63	0.90	0.56, 1.45	42/66	64	139/217	64	1.07	0.58, 1.99
Dipping	54/117	46	112/221	51	0.76	0.48, 1.22	31/66	47	110/217	51	0.78	0.43, 1.42
Squirting	41/117	35	51/221	23	1.82*	1.10, 3.01	17/66	26	51/217	24	1.22	0.62, 2.38
Spraying	32/117	27	42/221	19	1.57	0.92, 2.68	13/66	20	42/217	19	1.03	0.50, 3.23
Type of solvent used, ever/all												
Gasoline	71/101	70	133/193	69	1.19	0.69, 2.07	40/57	70	128/187	68	1.20	0.58, 2.48
Diesel fuel	21/101	21	32/193	17	1.38	0.72, 2.64	14/57	25	32/187	17	1.35	0.61, 3.00
Kerosene	6/101	6	24/193	12	0.44	0.17, 1.17	3/57	5	23/187	12	0.59	0.15, 2.26
Mineral spirits	6/101	6	14/193	7	0.65	0.23, 1.84	2/57	4	14/187	7	0.29	0.06, 1.56
Turpentine	8/101	8	16/193	8	0.82	0.32, 2.13	3/57	5	16/187	9	0.57	0.13, 2.40
Painting farm buildings, ever/all	115/246	47	259/448	58	0.64*	0.46, 0.89	65/131	50	254/436	58	0.66	0.43, 1.02
Painting farm buildings, hours/month	3.6 (10.8)		1.9 (2.6)		1.05	1.00, 1.10	4.1 (12.7)		1.8 (2.5)		1.05	0.99, 1.12
Varnishing, stripping, or staining, ever/all	71/236	30	146/440	33	0.84	0.59, 1.21	41/131	31	143/428	33	0.79	0.50, 1.26
Time spent varnishing, stripping, or staining, hours/year	6.2 (9.7)		5.7 (8.4)		1.01	0.98, 1.05	6.2 (10.1)		5.6 (8.3)		1.02	0.98, 1.06
Using wood preservative, ever/all	44/244	18	86/447	19	0.96	0.63, 1.47	25/133	19	84/436	19	0.91	0.53, 1.55
Time spent using wood preservative, hours/year	3.7 (5.6)		6.1 (10.2)		0.96	0.90, 1.01	3.3 (6.0)		6.2 (10.3)		0.94	0.86, 1.03
Type of wood preservative used, ever/all												
Creosote[g]	26/38	68	61/87	70	0.83	0.33, 2.11	11/20	55	59/85	69	0.42	0.13, 1.32
Pentachlorophenol	7/38	18	11/87	13	1.93	0.61, 6.10	6/20	30	11/85	13	4.55*	1.14, 18.1

Abbreviations: CI, confidence interval; OR, odds ratio; SD, standard deviation.

* $P < 0.05$.

[a] All data are mean values with standard deviations in parentheses unless otherwise specified.

[b] Numbers of definite positive or negative responses varied by question. Respondents who answered "no" to the general question about an activity were not asked more detailed questions.

[c] Adjusted for sex, age, 10-year age group, education, and state. Nonfarmers, persons who had lived on farms only as children, and persons who gave "don't know" responses were excluded—except that persons who had lived on farms as children were asked about the use of a mask or gloves, if they had handled pesticides. For continuous variables, odds ratios are for a 1-unit change.

[d] The numbers of participants who engaged in these tasks were too small to make further analyses meaningful.

[e] The welding hours model did not include sex, because only men provided data.

[f] Percentages total more than 100 because many participants had used more than 1 method.

[g] Percentages total less than 100 because many participants responded "paint."

the lower his or her glioma risk (per year of age, OR = 0.97, 95% CI: 0.95, 1.00).

We repeated the major analyses (i.e., grain ever being grown (vs. never)) separately for men and women (results not shown; data available from corresponding author). Because the numbers of participants were lower, confidence intervals were wider, and some variables that were statistically significant in combined analyses were no longer significant in separate analyses, although the direction of the association did not change. Percentages of male and female cases and controls reporting specific crops were similar. Women living or working on a farm where milo was grown were at statistically significantly increased risk of glioma. Seven cases (7%) and 4 controls (2%) reported that milo was grown (adjusted OR = 4.19, 95% CI: 1.13, 15.6). In an analysis excluding proxy respondents, men living or working on a farm where barley was grown were at statistically significantly increased risk of glioma (28 cases (37%) and 74 controls (29%) reported that barley was grown; adjusted OR = 2.15, 95% CI: 1.15, 4.03). Raising corn, rye, or soybeans was associated with statistically significantly decreased risks of glioma among men (results not shown).

Table 3 compares case and control responses regarding exposure to selected livestock: dairy cows, other cattle, chickens, and hogs. As with the crops, cases had generally been younger than or the same age as controls when livestock had first been raised on the farm, and livestock had generally been raised for more years on control farms. Cases reported personally killing chickens (but not dairy cows, other cattle, or hogs) at a significantly younger age than controls did. Living or working on a farm where hogs were raised was associated with a statistically significantly decreased risk of glioma (OR = 0.63, 95% CI: 0.43, 0.93). However, the more years a participant had butchered hogs, the greater was his or her risk of glioma (per year, OR = 1.15, 95% CI: 1.01, 1.33). The younger a participant was when he or she began killing chickens, the lower the risk of glioma (per year, OR = 0.97, 95% CI: 0.94, 0.99).

We repeated the major analyses (i.e., animals ever being raised (vs. never) and animals ever being killed (vs. never)) separately for men and women (data available from corresponding author). More than 50% of male participants but only 20%–25% of female participants had butchered cattle or hogs, while over 80% of men and women had killed chickens. Killing chickens was associated with a statistically significantly reduced risk of glioma for women (49 cases (83%) and 99 controls (97%) reported killing chickens; adjusted OR = 0.11, 95% CI: 0.03, 0.44). For men, living or working on a farm where hogs were raised was associated with reduced risk of glioma (153 cases (73%) and 226 controls (83%) reported living or working on a farm where hogs were raised; adjusted OR = 0.55, 95% CI: 0.33, 0.92).

Information about other farm tasks is presented in Table 4. Several imprudent practices in handling farm chemicals were associated with increased risk. Farmers who never washed their faces and hands or changed clothes immediately after applying pesticides were at significantly greater risk than those who ever cleaned up immediately (never washing up immediately, OR = 3.08, 95% CI: 1.78, 5.34; never changing clothes immediately, OR = 2.84, 95% CI: 1.04, 7.78). Those who never used personal protective equipment when applying pesticides, never wore gloves or ran the washing machine through an empty cycle after laundering pesticide-applicator clothes, or stored pesticides in the house rather than in an outbuilding were at non-statistically significantly increased risk of glioma. However, in analyses excluding proxies, persons who never used personal protective equipment when applying pesticides were not at increased risk. Farmers who squirted a solvent on tools they were cleaning were at significantly increased risk (OR = 1.82, 95% CI: 1.10, 3.01).

Ever painting farm buildings was associated with a decreased risk of glioma (OR = 0.64, 95% CI: 0.46, 0.89). The use of pentachlorophenol as a wood preservative was associated with a significantly increased risk in analyses excluding proxy respondents (OR = 4.55, 95% CI: 1.14, 18.1), but the number of users was small (6 cases, 11 controls). Similarly, personally applying nitrogen fertilizers to milo was associated with a significantly increased risk (OR = 5.58, 95% CI: 1.24, 25.2), but only a small number of participants had performed that task (7 cases, 4 controls).

We repeated the major analyses of farm tasks separately for men and women (data available from corresponding author). Approximately three-fourths of male participants and one-third of female participants had ever applied pesticides. Among those who did, never washing one's face and hands immediately after applying pesticides was associated with a statistically significantly increased risk of glioma in both sexes (for 81 male cases (81%) and 127 male controls (63%), adjusted OR = 2.71, 95% CI: 1.49, 4.91; for 15 female cases (83%) and 21 female controls (46%), adjusted OR = 10.5, 95% CI: 1.95, 57.1). In sex-specific analyses of farm tasks, painting farm buildings was associated with reduced risks for both men and women, but the result was statistically significant only for men (for 33 female cases (32%) and 73 female controls (41%), adjusted OR = 0.70, 95% CI: 0.41, 1.20; for 82 male cases (57%) and 186 male controls (69%), adjusted OR = 0.62, 95% CI: 0.40, 0.96).

Results for all crop, livestock, and task variables were similar when the analysis included nonfarmers or included only glioblastoma multiforme cases. For example, in analyses including nonfarmers, growing corn, oats, or soybeans again was associated with a statistically significantly decreased risk of glioma (for corn, OR = 0.71, 95% CI: 0.56, 0.90; for oats, OR = 0.71, 95% CI: 0.55, 0.90; and for soybeans, OR = 0.66, 95% CI: 0.51, 0.87), while in analyses including only glioblastoma multiforme cases, results were similar but not all statistically significant (for corn, OR = 0.34, 95% CI: 0.17, 0.68; for oats, OR = 0.64, 95% CI: 0.36, 1.14; and for soybeans, OR = 0.69, 95% CI: 0.45, 1.06).

DISCUSSION

Although farmers are generally at lower risk of cancer than the general population, possibly because of healthier lifestyles (i.e., lower smoking prevalence, more physical activity), several studies have shown an increased risk of brain cancer in farmers (3, 4, 20). This increased risk has been attributed to farm exposures (21, 22), presumably carcinogens, though some studies of farm exposures have shown no increased glioma risk (7–9). Our previous analyses of Upper Midwest Health Study data showed that neither exposure to particular pesticides nor general exposure to pesticides was associated with risk of glioma (10, 11). In the present analysis, we did see associations between some work practices and increased risk of glioma. Cleaning up after pesticide use, using personal protective equipment when applying pesticides, wearing gloves and running the washing machine through an empty cycle after laundering pesticide-applicator clothes, and not storing pesticides in the house would generally be considered prudent work practices. The differences in risk we observed for various methods of cleaning tools with solvents may have been due to chance. The use of pentachlorophenol as a wood preservative and the application of nitrogen fertilizers to milo were associated with significantly increased risk, but the numbers of cases and controls who had used pentachlorophenol or applied nitrogen fertilizers to milo were small.

Living or working on a farm where corn, oats, soybeans, or hogs were raised or ever painting farm buildings was associated with reduced risk of glioma. These variables may be surrogates for exposures we did not ask about that reduce glioma risk, or the findings may have been due to chance or a ''healthy farmer'' effect (9, 23). Information on the participants' involvement in raising these crops and livestock (which we do not have) might clarify the findings. Similarly, the association of older participant age when barley was first grown with increased glioma risk might be explained if we knew whether participants were actively raising barley, or it might be due to chance.

We did have information on participants' involvement in butchering tasks, but the results were not consistent. More years spent butchering hogs, but not younger age at first butchering or butchering of more hogs, was associated with increased risk of glioma. Younger age at first killing chickens, but not more years spent killing chickens or killing of more chickens, was associated with decreased risk of glioma.

There is ample evidence of an immunologic difference between farmers and their families and the nonfarm population in studies carried out in Europe and North America; persons living on a farm, particularly in early life, are less likely to have allergies (24–29), although there is some debate as to whether this results from early exposure to endotoxins or from the ''healthy farmer'' effect of allergic persons' moving out of the farm environment (23, 25, 30, 31). Whether this effect, studied mainly in children, carries through to adulthood, when farmers are repeatedly exposed to multiple allergens, remains to be clarified. Radon et al. (32) found fewer allergy-related outcomes among adults who had visited farm animal buildings regularly in early childhood than among adults who had not. An increased prevalence of allergy has been associated with a decreased risk of glioma (33–37). Farmers may be at higher risk of glioma because of their lower incidence of allergies (which may be due to farm exposures), rather than directly from farm exposures that are carcinogenic.

Strengths of this study include the large number of histologically confirmed gliomas and the use of population-based controls. General limitations include the large percentage of proxy case respondents, possible poor recall by case respondents, and the case-control age difference. For this analysis, specific limitations include the lack of comprehensive information about the crops and livestock raised; for example, we did not ask about the raising of nongrain crops such as vegetables and fruits or about livestock other than cattle, hogs, and chickens (such as turkeys, sheep, and horses). Participants were not asked about the extent of their involvement in cultivating the crops; this could have caused underestimation of pesticide exposure if participants had performed field tasks shortly after pesticide application, even if they did not apply the pesticide themselves (38–40). Participants also were not asked about the extent of their involvement in raising the livestock, except for cleaning of dairy cow barns. There were no questions about household pets; this would have been useful, given the strong association between contact with pets in the first year of life and resistance to allergies (24, 29, 41, 42). We did not ask participants who had lived on a farm as children but not as adults any farm-related questions, except those about pesticides. The ages participants reported they were when livestock had first been raised and when they had first butchered hogs and chickens (Table 3), all under age 18 years, show that it would have been useful to ask persons who had lived on a farm only as children the questions on farm activities.

In summary, the negative associations we saw may have been due to chance, a ''healthy farmer'' effect, or exposures which reduce glioma risk. We did find an increased risk for never cleaning up immediately after pesticide use and for storing pesticides in the house. Farmers' increased risk of glioma may be due to other activities or to an inverse association with allergies previously reported by other investigators.

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