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Neurologic Symptoms Associated With Cattle Farming in the Agricultural Health Study

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Abstract

Objective—Infection with *Campylobacter jejuni*, a bacterium carried by poultry and livestock, is the most frequently identified antecedent to the autoimmune neurologic condition Guillain-Barré Syndrome. We used Agricultural Health Study data to assess whether cattle farming was associated with prevalence of neurologic symptoms.

Methods—Prevalence of self-reported symptoms in cattle farmers ($n = 8878$) was compared with farmers who did not work with animals ($n = 7462$), using multivariate regression.

Results—Prevalence of numbness and weakness were increased for beef and dairy farmers compared with the reference group ($P < 0.0001$). Of cattle farmers, 48% did not report raising other animal species, and prevalence of numbness and weakness were also increased in this subgroup compared with the reference group ($P < 0.02$).

Conclusions—Occupational exposure to cattle was associated with increased prevalence of self-reported symptoms associated with peripheral neuropathy.

Recent research[1,2] indicates that occupational exposure to farm animals at several stages of food production may be an important source of exposure to pathogens. The bacterial pathogen *Campylobacter jejuni* is particularly common in poultry but can also colonize swine and other livestock, including cattle.[3] *Campylobacter* spp. is the most commonly identified bacterial cause of foodborne illness in the United States,[4] and campylobacteriosis is the leading cause of bacterial diarrhea worldwide.[5] Although food-borne exposure is an important source of *Campylobacter* infection, case–control studies[6,7] have demonstrated significant positive associations between exposure to farm animals, including cattle, and *Campylobacter* infection. Elevated levels of anti–*C. jejuni* antibodies have been reported in meat processing workers,[8] poultry workers,[9] and slaughterhouse workers.[2]

Infection with *C. jejuni* is the most frequently identified antecedent to Guillain-Barré Syndrome (GBS), an autoimmune peripheral neuropathy.[10–12] GBS is the leading cause of

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acute flaccid paralysis in the United States and worldwide.[13] The incidence of GBS after *C. jejuni* infection has been estimated to be about 1.17 per 1000 person-years, but certain strains of *C. jejuni* are more strongly associated with GBS.[14,15] Evidence indicates that the mechanism for the association between *C. jejuni* exposure and GBS involves molecular mimicry between *C. jejuni* lipo-oligosaccharides and peripheral nerve gangliosides.[16–21]

Peripheral neuropathy, whether motor or sensory, can have varying degrees of severity and can be due to various causes. In GBS, the mechanism of neuropathy is autoimmune. The two most prominent types of GBS are acute inflammatory demyelinating polyradiculoneuropathy (AIDP), which is the most common type of GBS in North America and Europe, and acute motor axonal neuropathy (AMAN), which is most common in China and Mexico.[12,22,23] Weakness is a symptom of both AIDP and AMAN, whereas numbness is more associated with AIDP. In addition to GBS with its acute manifestation, there also is a disease with a longer but heterogeneous course, called chronic inflammatory demyelinating polyradiculoneuropathy, which also exhibits features characteristic of autoimmune disease.[24,25] AMAN is most strongly associated with *C. jejuni* infection, but there is evidence that other forms of autoimmune peripheral neuropathy may be associated with *C. jejuni* as well.[26] Although the symptoms of GBS are often severe, with 80% to 90% of GBS patients becoming unable to walk during their illness, we hypothesize that some people exposed to *C. jejuni* may experience subclinical, or less severe, symptoms of autoimmune peripheral neuropathy.[27,28]

Despite the evidence that occupational exposure to animals may be an important source of *Campylobacter* infection, few studies have examined these exposures to *C. jejuni* as a risk factor for development of peripheral neuropathy. In 2007, Price et al[9] reported for the first time that poultryhouse workers ($n = 20$) had significantly increased odds of reporting symptoms of peripheral neuropathy compared with community referents ($n = 40$). Furthermore, among men reporting poultry contact ($n = 18$), levels of anti–*C. jejuni* antibodies were significantly higher, and immunoglobulin G antiganglioside autoantibodies associated with autoimmune peripheral neuropathy were increased as compared with male controls ($n = 18$), but with borderline statistical significance ($P = 0.074$).[9] Davis et al[29] used the large sample size of the Agricultural Health Study (AHS) to build on the findings of Price et al, documenting that self-reported work with swine or with both swine and poultry was significantly associated with symptoms of peripheral neuropathy.

Campylobacter has been of particular concern in poultry, but there has also been recent attention to the role of cattle as reservoirs of *Campylobacter*.[30] We hypothesize that occupational exposure to cattle may increase the risk of *C. jejuni*–associated autoimmune peripheral neuropathy, including less severe, or subclinical, peripheral neuropathy. This study examines the association between occupational exposure to dairy or beef cattle and neurologic symptoms in AHS participants.

METHODS

This study used data from phase I of the AHS, which was originally designed to assess associations between pesticides and other farm-related exposures and cancer and other health outcomes.[31] The AHS recruited private pesticide applicators (most of whom were farmers) and commercial applicators applying for pesticide licenses in Iowa and North Carolina during phase I of the AHS, which occurred between 1993 and 1997.[31] Pesticide license renewal is required every 3 years in Iowa and North Carolina; all individuals applying for new or renewed pesticide licenses were invited to enroll in the AHS. The AHS cohort includes more than 89,000 participants including approximately 52,400 private pesticide applicators, 5000 commercial applicators, and 32,300 spouses of private applicators. The present study is a nested cross-sectional study using data collected at enrollment (p1rel0712.01 AHS phase I data release). Further details about the AHS can be found at http://aghealth.nci.nih.gov/ and AHS questionnaires are accessible at http://aghealth.nci.nih.gov/questionnaires.html.

This analysis was restricted to private pesticide applicators who completed both the enrollment questionnaire and the take-home farmer–applicator questionnaire because information about neurologic symptoms was collected with the latter. We excluded commercial pesticide applicators because they were less likely to work with animals.[31] We also excluded persons from this study if they were missing data about any of the nine animal exposures or any of the five neurologic symptoms of interest. Forty-four percent of the private pesticide applicators, a total of 22,916, completed both questionnaires, and of these, 20,599 had complete data for the exposures and outcomes of interest.

Cattle exposure was assessed on the basis of the following question from the AHS enrollment questionnaire: “What are the major income producing crops and animals you are currently raising on a farm? (Mark all that apply).” Marking at least one of the following indicated animal exposure: “beef cattle,” “dairy cattle,” “hogs/swine,” “poultry,” “sheep,” “eggs,” and “other farm animals.” An additional question from the enrollment questionnaire was used in defining the reference group: “Which of the following activities do you perform at least once each year? (Mark all the activities you perform).” Subjects who reported “work in swine confinement areas” or “work in poultry areas” were considered to be exposed to animals. The 7462 participants who did not report working with any of the earlier nine animal categories were classified as the unexposed reference group. The 8878 participants who reported working with either “beef cattle” or “dairy cattle” were classified as cattle farmers. This study compared 8878 cattle farmers with 7462 farmers who reported no farm animal exposures, with a total sample size of 16,340. Fifty-two percent of the cattle farmers also farmed other animals. To distinguish between exposure to cattle and exposure to other animals such as poultry that may harbor *C. jejuni*, the 4275 farmers who worked with cattle but no other farm animals were also assessed as a subgroup.

Beef farmers and dairy farmers also were assessed as separate subgroups of cattle farmers because of the possibility that occupational conditions and practices might differ between these two groups, or that beef and dairy cattle might have different levels of *C. jejuni*. These two groups are not mutually exclusive, as 426 of the participants reported working with both beef and dairy cattle. Of the 8878 cattle farmers, 7710 farmed beef cattle only, 742 farmed dairy cattle only, and 426 farmed both beef and dairy cattle. Thus, there were a total of 8136 beef farmers (7710 who worked with beef cattle only and 426 who worked with both beef and dairy cattle) and a total of 1168 dairy farmers (742 who worked with dairy cattle only and 426 who worked with both beef and dairy cattle). Each of the four groups (all cattle farmers and the three subgroups: farmers who worked only with cattle and no other animals, beef farmers, and dairy farmers) were individually compared with the reference group of 7462 farmers who did not report working with any farm animals.

Neurologic symptoms were assessed on the basis of the following question on the AHS farmer–applicator questionnaire: “Approximately how often during the last 12 months have you experienced the following?” Twenty-three symptoms were queried on the basis of hypothesized outcomes of pesticide exposures. The original responses were “never,” “once a year,” “once a month,” “once a week,” and “more than once a week.” The latter four categories were collapsed into one so that analysis was based on a recoded dichotomous variable of never experienced the symptom during the past 12 months, versus experienced the symptom at least once in the past 12 months. Five of the symptoms were selected for assessment: “numbness or pins-and-needles in your hands or feet,” “weakness in your arms or legs," "difficulty speaking," "blurred vision or double vision," and "difficulty seeing at night." The first two symptoms were selected as consistent with peripheral neuropathy, whereas the other three symptoms are not typical of peripheral neuropathy but may be associated with other neurological conditions.[27,28]

The association between self-reported exposure to cattle and neurologic symptoms was assessed using a similar analytic framework as used by Davis et al.[29] Because the study design was cross-sectional, prevalence ratios (PRs) were calculated to assess the prevalence of self-reported neurologic symptoms in those exposed to cattle compared with the reference group of those with no reported farm animal exposure. Because they directly estimate PRs, univariate and multivariate log-binomial regression analyses were performed using SAS® 9.2 software (SAS Institute, Cary, NC) as described by Spiegelman and Hertzmark.[32]

On the basis of the hypothesized causal pathway between exposure to cattle and symptoms of peripheral neuropathy, the following variables were chosen *a priori* for inclusion in multivariate modeling: state (Iowa or North Carolina), gender (male or female), race (non-Hispanic white or other), ever smoker (yes or no), ever consume alcohol in the past year (yes or no), age (categorical), education (beyond high school vs high school or less), frequency of consumption of each of the five types of meat or poultry products (categorical), and use of each of the four categories of pesticides (yes or no): insecticides, herbicides, fungicides, or fumigants. Food consumption, particularly of beef, pork, and poultry products, was an important consideration because *C. jejuni* is a common food-borne pathogen in the United States.[4] Pesticide use was included because it has been associated with neurologic symptoms in AHS participants.[33] Organophosphate insecticides, in particular, may be used to control insects in cattle farming and have been associated with neurologic symptoms. Therefore, PRs were also assessed in an additional model that included the covariates discussed earlier, with ever mixed or applied organophosphates (yes or no) replacing the less specific insecticides variable.

RESULTS

Demographic and other relevant characteristics of the cattle farmers and the reference group are presented in Table 1. All individual groups differed significantly, but in small magnitude, from the reference group on gender, race, state, education, smoking, alcohol consumption, and use of insecticides, fungicides, and fumigants, age, and consumption of hamburgers, beef-steaks, chicken, and pork chops or ham steak. The majority of cattle farmers (77.3%) were from Iowa, whereas only 49% of farmers in the reference group were from Iowa. The mean age of cattle farmers was 3.5 years less than the mean age of the reference group. A smaller proportion of cattle farmers had education beyond high school, and fewer cattle farmers reported smoking, whereas more reported alcohol consumption compared with the reference group. Cattle farmers reported more frequent consumption of hamburgers and beef-steaks than did the reference group. A greater proportion of cattle farmers used insecticides compared with the reference group. Less than 4% of the data for covariates were missing for cattle farmers and the reference group.

The prevalence of self-reported neurologic symptoms is presented in Table 2. Overall, the prevalence of the five symptoms from most to least prevalent was: numbness (27.3%), weakness (15.3%), night blindness (12.1%), blurred vision (10.8%), and speech problems (4.4%). PR estimates are presented in Table 3. Cattle farmers overall and all the three cattle farmer subgroups had statistically significant positive associations for self-reported numbness and weakness compared with the reference group in both the unadjusted and adjusted models.

In the adjusted model, prevalence of reported numbness (PR = 1.22; 95% confidence interval [CI], 1.12–1.32]) and weakness (PR = 1.25; 95% CI, 1.14–1.38) was increased for cattle farmers compared with the reference group. Significant increases in prevalence of numbness and weakness remained for the three subgroups of cattle farmers (Table 3). The PR for numbness in cattle farmers with no other animals compared with the reference group was 1.15 (95% CI, 1.04–1.26). The PR for weakness in cattle farmers with no other animals compared with the reference group was 1.16 (95% CI, 1.03–1.30). For the other three neurologic symptoms (speech problems, blurred vision, and night blindness), PRs were not statistically significant in the adjusted models, with the exception of an increased prevalence of blurred vision in dairy farmers (Table 3). PR estimates and CIs remained similar when further adjusted for organophosphate use.

DISCUSSION

The prevalence of both reported numbness and reported weakness was increased in cattle farmers as a group and in the three subgroups of cattle farmers compared with farmers who did not work with animals. This association is consistent with, but does not specifically indicate, an association between occupational exposures in cattle farming and increased prevalence of *C. jejuni*–associated autoimmune peripheral neuropathy. The lack of similarly strong differences in prevalence of reported speech problems, blurred vision, and night blindness supports this possibility, as these three symptoms are generally not associated with autoimmune peripheral neuropathy.[27]

Of the AHS participants in the current study who reported raising cattle, 52% also reported raising other animals, including poultry, swine, and sheep. Because these other farm animals are known to carry *C. jejuni*, we also assessed the prevalence of symptoms in those participants who reported working with cattle but no other farm animals. Significant increases in prevalence of numbness and weakness remained for those farmers who farmed only cattle, although the PRs were lower and the *P* values were higher. These findings suggest that exposure to cattle in the absence of other farm-animal exposures is associated with increased symptoms of peripheral neuropathy, and highlight a need for further research on *C. jejuni* exposure via cattle.

The prevalence of symptoms of peripheral neuropathy was increased for both beef farmers and dairy farmers. Beef farmers and dairy farmers were not directly compared with each other, but the PRs for reported symptoms of both numbness and weakness compared with the reference group were particularly high for dairy farmers. One study[34] of 56 beef and dairy farms in the United Kingdom demonstrated that the presence of dairy cows was associated with increased odds of *Campylobacter* detection, but that finding is not necessarily generalizable to the AHS population. The prevalence of *C. jejuni* in the beef and dairy cattle raised by the farmers in the present study is unknown. Dairy farmers generally work with cattle indoors and may have more intensive animal contact that might lead to increased *C. jejuni* exposures, but this speculation would require further study to confirm. Also, different farming practices might lead to differences in pathogen shedding or differing job tasks might influence risks of pathogen transmission between cattle and humans. It is also possible that beef and dairy farmers might differ in exposure to an unmeasured factor other than *C. jejuni* that might contribute to symptoms of peripheral neuropathy.

The prevalence of *Campylobacter* in cattle may vary on the basis of herd type and herd characteristics.[35–39] Globally, *Campylobacter* spp. has been detected in 6% to 64% of dairy cattle and 42% to 83% of beef cattle, based on studies in 21 different countries.[5] The United States 2002 National Animal Health Monitoring Survey, a program coordinated by the US Department of Agriculture,[40] reported *Campylobacter* spp. in 51% of 1435 individual cows sampled and nearly 98% of 96 dairy herds sampled from 21 states, with *C. jejuni* as the most common type.[41] This was an increase from the 1996 National Animal Health Monitoring Survey,[39] which reported detection of *C. jejuni* in 37.7% of dairy cattle fecal samples, with greater than 25% of cows testing positive for *C. jejuni* in 80.6% of herds. Studies in various local regions of the United States have also documented high rates of *Campylobacter* in cattle.[42–45]

The prevalence of *C. jejuni* in cattle on the specific farms of the subjects of this study during the study time period is unknown, but limited information about the prevalence of *C. jejuni* in cattle in Iowa and in the eastern United States is available for periods before and after the study time period. *C. jejuni* was culture-confirmed in fecal samples from 24% of 358 dairy cattle and 19% of 252 beef cattle sampled between 2001 and 2003 at a commercial beef packing plant in the southeastern United States that received cattle from several areas in the eastern United States.[43] The prevalence of thermophilic *Campylobacter* detected in the bile of 477 cull dairy cows at a central Iowa packing plant in the early 1980s was 15.5%, and 91% of these *Campylobacter* isolates were *C. jejuni*.[45]

Inferences as to a potential role of *C. jejuni* exposure in the observed symptoms are limited by a lack of specific information about *C. jejuni* exposure for the individuals or groups in this analysis. Exposure to other unmeasured risk factors, including other pathogens, may have been involved as other pathogens have been associated with GBS.[11] Moreover, the observed increase in prevalence of symptoms of numbness and weakness may or may not be associated with autoimmune pathophysiology. These symptoms are not specific to autoimmune peripheral neuropathy and may be attributed to other causes that do not involve autoimmune mechanisms, such as physical trauma. We conducted this research on the basis of the hypothesis that cattle farmers would have an increased prevalence of symptoms due to increased *C. jejuni* exposure, and attempted to adjust for other potential contributors to neurologic symptoms, including pesticide exposure. The results were reassuringly similar when we adjusted for organophosphate use, but the possibility remains that cattle farmers may differ from farmers who do not work with animals on more specific pesticide exposures, and that such differences might account for some of the observed increase in prevalence of numbness and weakness in cattle farmers. It is also possible that cattle farmers may be more susceptible to repetitive motion injuries or to cold or to some other unmeasured precursor to symptoms of numbness and weakness. Thus, the findings of this study indicate that cattle farmers in the AHS have an increased prevalence of symptoms of numbness and weakness, but do not confirm the cause of these symptoms. Specific measurement of anti–*C. jejuni* antibodies and antiganglioside autoantibodies would be necessary to rule out other possible causes. The symptoms were self-reported and the data were obtained using a questionnaire that was not originally designed to assess risks of autoimmune peripheral neuropathy. Further information, such as nerve conduction velocity tests and electromyography, would be needed for diagnostic purposes. Because such diagnostic information was not available for this study, it is not clear what kind of neuropathy process, if any, may have contributed to the observed symptoms. Longitudinal assessment of serum antiganglioside autoantibodies associated with GBS could provide further information about whether the observed symptoms may be associated with subclinical autoimmune peripheral neuropathy. Thus, future research using biomarkers, particularly anti–*C. jejuni* antibodies and antiganglioside autoantibodies, could more specifically assess whether the observed increase in symptoms of numbness and weakness in cattle farmers is due to *C. jejuni*–associated autoimmune pathophysiology.

Another limitation of the study is that PRs might be underestimated due to the healthy worker effect. Farmers who experienced significant adverse symptoms while working with cattle might have chosen to stop working with cattle before the initiation of the study.

Because participants were only asked about current animal exposures, such participants who might have previously switched from animal farming to crop farming would be included in the reference group, which would decrease the observed association.

Despite the high prevalence of *Campylobacter* in cattle, there is a dearth of research on peripheral neuropathy in cattle farmers, and this study provides important information and rationale for further research to address this issue. The nesting of this study within the AHS provides several strengths including a large sample size, a relevant reference group, the ability to adjust for important potential confounders, and the ability to assess the prevalence of self-reported symptoms of peripheral neuropathy as well as neurologic symptoms that are not typical of peripheral neuropathy.

The findings of this study indicate that occupational exposure to cattle is associated with symptoms of peripheral neuropathy. Further clarification of this potentially important health risk would be beneficial to informing the development and implementation of policies to protect the health of farmworkers and rural communities.

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TABLE 1

Characteristics of 16,340 Participants in the Agricultural Health Study, 1993–1997

	All Cattle Farmers (Beef, Dairy, or Both)*	Cattle Farmers With No Other Farm Animals	Beef Farmers	Dairy Farmers	Reference†
N	8,878	4,275	8,136	1,168	7,462
Gender, *n* (%)					
Male	8,733 (98.4)	4,198 (98.2)	8,006 (98.4)	1,150 (98.5)	7,216 (96.7)
Female	145 (1.6)	77 (1.8)	130 (1.6)	18 (1.5)	246 (3.3)
Race, *n* (%)					
Non-Hispanic white	8,745 (98.5)	4,211 (98.5)	8,014 (98.5)	1,148 (98.3)	7,212 (96.7)
Other	122 (1.4)	58 (1.4)	111 (1.4)	20 (1.7)	240 (3.2)
Missing	11 (0.1)	6 (0.1)	11 (0.1)	0	10 (0.1)
State, *n* (%)					
North Carolina	2,012 (22.7)	1,512 (35.4)	1,860 (22.9)	221 (18.9)	3,818 (51.2)
Iowa	6,866 (77.3)	2,763 (64.6)	6,276 (77.1)	947 (81.1)	3,644 (48.8)
Age, mean (yr)	47.7	49.9	48.0	45.0	51.2
Education, *n* (%)					
≤High school	5,173 (58.3)	2,519 (58.9)	4,685 (57.6)	773 (66.2)	4,118 (55.2)
>High school	3,564 (40.1)	1,681 (39.3)	3,316 (40.7)	382 (32.7)	3,183 (42.6)
Missing	141 (1.6)	75 (1.8)	135 (1.7)	13 (1.1)	161 (2.2)
Smoking: ever, *n* (%)	3,611 (40.7)	1,939 (45.4)	3,388 (41.6)	366 (31.3)	4,023 (53.9)
Missing	9 (0.1)	2 (0.05)	9 (0.1)	0	15 (0.2)
Alcohol: ever, *n* (%)	5,823 (65.6)	2,581 (60.4)	5,344 (65.7)	767 (65.7)	4,181 (56.0)
Missing	215 (2.4)	126 (2.9)	198 (2.4)	26 (2.2)	215 (2.9)
Food frequency in last year					
Hamburger, median	Twice a week	Twice a week	Twice a week	Twice a week	Once a week
Missing, *n* (%)	82 (0.9)	46 (1.1)	76 (0.9)	9 (0.8)	84 (1.1)
Beef-steaks, median	Once a week	Once a week	Once a week	Once a week	2–3 times a month
Missing, *n* (%)	152 (1.7)	87 (2.0)	140 (1.7)	18 (1.5)	161 (2.2)
Chicken, median	Once a week	Once a week	Once a week	Once a week	Once a week
Missing, *n* (%)	131 (1.5)	70 (1.6)	121 (1.5)	14 (1.2)	125 (1.7)
Pork-chops or ham steak, median	Once a week	2–3 times a month	Once a week	2–3 times a month	2–3 times a month

	All Cattle Farmers (Beef, Dairy, or Both)*	Cattle Farmers With No Other Farm Animals	Beef Farmers	Dairy Farmers	Reference†
Missing, *n* (%)	115 (1.3)	72 (1.7)	104 (1.3)	16 (1.4)	112 (1.5)
Bacon or breakfast sausage, median	2–3 times a month	2–3 times a month	2–3 times a month	2–3 times a month	2–3 times a month
Missing, *n* (%)	96 (1.1)	55 (1.3)	85 (1.0)	15 (1.3)	96 (1.3)
Pesticides: ever use, *n* (%)					
Insecticide	8,364 (94.2)	3,993 (93.4)	7,666 (94.2)	1,108 (94.9)	6,703 (89.8)
Missing	0	0	0	0	1 (0.01)
Herbicide	8,716 (98.2)	4,171 (97.6)	7,998 (98.3)	1,137 (97.3)	7,200 (96.5)
Missing	0	0	0	0	0
Fungicide	2,247 (25.3)	1,362 (31.9)	2,125 (26.1)	204 (17.5)	3,280 (44.0)
Missing	1 (0.01)	0	1 (0.01)	0	4 (0.05)
Fumigant	1,534 (17.3)	998 (23.3)	1,473 (18.1)	105 (9.0)	2,147 (28.8)
Missing	3 (0.03)	2 (0.05)	3 (0.04)	0	8 (0.1)

*Cattle farmers may raise beef cattle or dairy cattle and 426 of them raised both beef and dairy cattle. Cattle farmers may also raise other animals on their farm. Thus, the following groups: cattle farmers with no other farm animals, beef farmers, and dairy farmers are subgroups of the overall group of cattle farmers.

†Reference group has no self-reported animal farming exposure.

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TABLE 2

Prevalence of Neurologic Symptoms Among 16,340 Participants in the Agricultural Health Study, 1993–1997

	Numbness, *n* (%)	**Weakness, *n* (%)**	**Speech Problems, *n* (%)**	**Blurred Vision, *n* (%)**	**Night Blindness, *n* (%)**
All cattle farmers (*n* = 8,878)	2,598 (29.3)	1,455 (16.4)	407 (4.6)	975 (11.0)	1,031 (11.6)
Only cattle (*n* = 4,275)	1,191 (27.9)	678 (15.9)	175 (4.1)	464 (10.9)	509 (11.9)
Beef farmers (*n* = 8,136)	2,364 (29.1)	1,328 (16.3)	372 (4.6)	883 (10.9)	942 (11.6)
Dairy farmers (*n* = 1,168)	379 (32.5)	213 (18.2)	61 (5.2)	141 (12.1)	137 (11.7)
Reference (*n* = 7,462)	1,865 (25.0)	1,040 (13.9)	308 (4.1)	784 (10.5)	944 (12.7)
Total sample	4,463 (27.3)	2,495 (15.3)	715 (4.4)	1,759 (10.8)	1,975 (12.1)

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TABLE 3

Prevalence Ratio Estimates for Neurologic Symptoms Among 16,340 Participants in the Agricultural Health Study, 1993–1997: Cattle Exposure Compared With No Farm Animal Exposure

	Numbness	Weakness	Speech Problems	Blurred Vision	Night Blindness
All cattle farmers (beef, dairy, or both) (*n* = 8,878) compared with reference group (*n* = 7,462), Total *N* = 16,340					
Unadjusted model (*n* = 16,340)					
Prevalence ratio [95% CI]	**1.24 [1.16–1.33]**	**1.21 [1.11–1.32]**	1.12 [0.96–1.30]	1.05 [0.95–1.16]	**0.91 [0.83–0.997]**
P	***P* < 0.0001**	***P* < 0.0001**	*P* = 0.155	*P* = 0.329	***P* = 0.043**
Adjusted model (*n* = 15,008)					
Prevalence Ratio [95% CI]	**1.22 [1.12–1.32]**	**1.25 [1.14–1.38]**	0.97 [0.82–1.16]	1.10 [0.99–1.24]	0.94 [0.84–1.05]
P	***P* < 0.0001**	***P* < 0.0001**	*P* = 0.752	*P* = 0.087	*P* = 0.253
Cattle farmers with no other farm animals (n = 4,275) compared with reference group (*n* = 7,462), Total *N* = 11,737					
Unadjusted model (*n* = 11,737)					
Prevalence ratio [95% CI]	**1.16 [1.07–1.26]**	**1.16 [1.05–1.29]**	0.99 [0.82–1.20]	1.04 [0.92–1.17]	0.93 [0.83–1.05]
P	***P* = 0.0007**	***P* = 0.005**	*P* = 0.929	*P* = 0.557	*P* = 0.239
Adjusted model (*n* = 10,685)					
Prevalence ratio [95% CI]	**1.15 [1.04–1.26]**	**1.16 [1.03–1.30]**	0.93 [0.76–1.14]	1.05 [0.92–1.20]	0.93 [0.82–1.06]
P	***P* = 0.004**	***P* = 0.012**	*P* = 0.475	*P* = 0.446	*P* = 0.269
Beef farmers (*n* = 8,136) compared with reference group (*n* = 7,462), Total *N* = 15,598					
Unadjusted model (*n* = 15,598)					
Prevalence ratio [95% CI]	**1.23 [1.14–1.32]**	**1.21 [1.10–1.32]**	1.11 [0.95–1.30]	1.04 [0.94–1.15]	**0.90 [0.82–0.996]**
P	***P* < 0.0001**	***P* < 0.0001**	*P* = 0.174	*P* = 0.484	***P* = 0.040**
Adjusted model (*n* = 14,314)					
Prevalence ratio [95% CI]	**1.21 [1.12–1.31]**	**1.24 [1.12–1.37]**	0.97 [0.81–1.15]	1.08 [0.96–1.21]	0.94 [0.84–1.05]
P	***P* < 0.0001**	***P* < 0.0001**	*P* = 0.720	*P* = 0.184	*P* = 0.247
Dairy farmers (*n* = 1,168) compared with reference group (*n* = 7,462), Total *N* = 8,630					
Unadjusted model (*n* = 8,630)					
Prevalence ratio [95% CI]	**1.44 [1.26–1.65]**	**1.38 [1.17–1.62]**	1.28 [0.97–1.70]	1.17 [0.97–1.42]	0.92 [0.76–1.11]
P	***P* < 0.0001**	***P* = 0.0001**	*P* = 0.086	*P* = 0.108	*P* = 0.377
Adjusted model (*n* = 7,863)					
Prevalence ratio [95% CI]	**1.40 [1.21–1.63]**	**1.43 [1.19–1.72]**	0.98 [0.71–1.35]	**1.31 [1.05–1.63]**	0.97 [0.79–1.20]
P	***P* < 0.0001**	***P* < 0.0001**	*P* = 0.887	***P* = 0.015**	*P* = 0.798

Prevalence ratios of neurologic symptoms for cattle farmers compared with 7,462 farmers without any self-reported exposure to farm animals.

Adjusted Model covariates: state, race, gender, age, education, alcohol consumption, smoking, frequency of consumption of hamburger, beef-steaks, chicken, pork chops/ham steak, and bacon/sausage, and exposure (yes/no) to insecticides, herbicides, fungicides, and fumigants.

Results significant at $P < 0.05$ are bolded.

CI, confidence interval.