Applied Occupational and Environmental Hygiene

ISSN: 1047-322X (Print) 1521-0898 (Online) Journal homepage: https://www.tandfonline.com/loi/uaoh20

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To cite this article: Mark J. Nieuwenhuijsen , Marc B. Schenker , Steven J. Samuels , Jeff A. Farrar & Shelly S. Green (1996) Exposure to Dust, Noise, and Pesticides, Their Determinants, and the Use of Protective Equipment among California Farm Operators, Applied Occupational and Environmental Hygiene, 11:10, 1217-1225, DOI: 10.1080/1047322X.1996.10389400

To link to this article: https://doi.org/10.1080/1047322X.1996.10389400

Exposure to Dust, Noise, and Pesticides, Their Determinants, and the Use of Protective Equipment Among California Farm Operators

Mark J. Nieuwenhuijsen, Marc B. Schenker, Steven J. Samuels, Jeff A. Farrar, and Shelly S. Green

Division of Occupational/Environmental Medicine and Epidemiology, Department of Internal Medicine and Institute of Toxicology and Environmental Health, University of California, Davis, California 95616

California has a very diverse and productive agricultural industry. We studied the determinants of the exposure to dust, noise, and pesticides and the use of protective equipment among 1947 randomly selected California farm operators. The farm operators completed a telephone interview during 1993 and were asked about work and farm characteristics and use of protective equipment. The median farm size was 60 acres. There were considerable differences in the self-reported percentage of time working in a dusty job and in a noisy job, and in the number of days using pesticides, between types of farming and between regions. Field crop farm operators reported the highest percentages of time in noisy or dusty jobs (median noise 30%, dust 20%) and nursery farmers reported the lowest (median noise 1%, dust 0%). Pesticide use varied among farm categories, with 5.4 percent of the livestock farmers and 37.1 percent of the nursery farmers reporting ten pesticide days or more per year. One of the strongest and most plausible predictors of exposure to dust and noise was the percentage of time driving a tractor. The use of protective equipment increased with an increase in the number of pesticide days and noise exposure, but did not increase with an increase in dust exposure. This article provides unique statewide information on exposure in California farming and can be used for epidemiological studies and to set priorities in health and safety. © *1996 AIH.* NIEUWENHUIJSEN, M.J.; SCHENKER, M.B.; SAMUELS, S.J.; FARRAR, J.A.; GREEN, S.S.: EXPOSURE TO DUST, NOISE, AND PESTICIDES, THEIR DETERMINANTS, AND THE USE OF PROTECTIVE EQUIPMENT AMONG CALIFORNIA FARM OPERATORS. APPL. OCCUP. ENVIRON. HYG. 11(10):1217–1225; 1996.

Farming has been associated with a wide variety of hazardous exposures.[1] Several studies have measured the exposure to dust and its constituents,[2–4] noise,[5] and pesticides,[6–8] but these generally were conducted on a small number of farms and a limited number of commodities. Exposure assessment in agriculture is difficult because of the varied and cyclic nature of the farmers' work and the diverse locations of the farms, and has therefore often been carried out by questionnaire or telephone interview. Exposures may vary with local farming practices, commodities grown or raised, geography, climate, and other factors. Exposure assessment and analyses of exposure determinants are important for understanding the exposures that may contribute to the development of disease, and are valuable for directing disease prevention efforts. They also can be used to set priorities in health and safety. In farming, dust exposure has been associated with respiratory disease;[9–11] pesticide exposure with cancer,[12,13] respiratory disease,[14] and adverse reproductive effects;[15] and noise exposure with hearing loss.[16,17]

In California, farm size, quantity and variety of commodities, agricultural practices, soil types, and climate are substantially different from those in other parts of the United States. In 1992 California's farmers sold an estimated $18.1 billion of farm products, making it the largest agricultural state based on cash receipts. That year, California had some 81,000 farms with an average size of 368 acres.[18] From our data we estimated that 1.5 million people were directly employed on farms in California. California agriculture produces approximately 250 different crops, and California leads the nation in the production of over 60 crops and livestock commodities, including eggs, broccoli, almonds, lemons, wine grapes, and safflower.[18] The large diversity of California farming is associated with a range of potentially hazardous exposures, but there has been little investigation of the magnitude and determinants of these exposures.

This article describes the self-reported exposure to dust, noise, and pesticides and use of protective equipment in a statewide random sample of California farm operators. It describes the differences in exposure between various types of farming, and it explores determinants of the self-reported exposures.

Materials and Methods

Sample Selection

To get 2000 interviews, based upon estimates from a previous pilot survey, a random sample of 4500 farms was selected from the California Agricultural Statistics Service (CASS) list of approximately 57,000 farms in California. A farm is defined by CASS as a location that produced $1000 or more in sales of agricultural products during the previous year. This study was directed to the primary operator of the farm on the CASS list frame. Of the 4500 farm operators, 3711 (82.5%) could be traced and contacted by phone. Of these 3711 farm operators, 2422 (65.3%) were eligible (>$1000 in sales) for the study and 1947 (80.4%) of these completed a telephone-administered questionnaire. The telephone interviews were carried out by a professional institute that routinely conducts telephone interviews. The 1289 (34.7%) ineligible farm operators included those who no longer operated a farm (n = 1042), those who

had died (n = 134), and those who spoke no English (n = 113). The farm operators were classified as "unable to contact by phone" only after a minimum of 12 calls were made to an apparently functional, correct phone number. No more than two calls per day (one morning and one afternoon) were permitted. Additional information on the sample, its selection, and its representation of California agriculture has been reported elsewhere.[19] Briefly, the main differences between our sample and the 1987 United States Agricultural Census were as follows: our sample had a slightly higher proportion of female farm operators (10.1 versus 6.3%), a higher mean acreage compared with the California Agricultural Census and the United States Agricultural census (1057 versus 368 and 462), and a lower proportion of small (1 to 9 acres) and large (>999 acres) farms compared with the California Agricultural Census and the United States Census results.[19]

The telephone-administered questionnaire included, among others, questions on the size and kinds of commodities grown or raised; percentage of time spent on various work practices; percentage of time spent working in a dusty job and in a noisy job; number of days mixing, loading, and applying pesticides; and use of protective equipment.

Farm Categorization

An industrial hygienist categorized the farm operators by their primary commodity groupings: field crops, fruit and nuts, livestock, nursery, vegetables, or "mixed" if they had two or more. Farms were categorized as small, based on an economic definition, when they grew no more than 20 acres of fruit or nuts, 90 acres of field crops, 32.5 acres of vegetables, and 20 acres of nursery products, and raised no more than 20,000 chickens and turkeys, 130 head of cattle, 60 swine, 10 horses, 50 rabbits, 200 hives of bees, and 20,000 pounds of fish (Pete Livingston, Cooperative Extension, University of California, Davis, personal communication). Large farms were categorized as single commodity grouping farms if the amounts of other commodities were small: no more than 5 acres of fruits or nuts, 2.5 acres of vegetables, 2.5 acres of nursery, and 20 acres of field crops, and no more than 20 chickens or turkeys, 10 head of cattle, 10 swine, 5 horses, 10 rabbits, 10 hives of bees, and 500 pounds of fish.

Region Categorization

California was divided into six different regions according to the production regions described by McCorkle and Nuckton:[20] the north coast, mountain, central coast, Sacramento Valley, San Joaquin, and southern regions.

Statistical Analyses

The self-reported percentages of time working at a dusty job and working at a noisy job, and the self-reported number of days mixing, loading, and applying pesticides (pesticide days) did not show a normal distribution. A large number of subjects reported zero percentage or days (dusty job 22.4%, noisy job 18.3%, pesticide days 54.1%), and for those who reported anything the distribution was skewed to the right. Therefore, any analyses used to explore determinants for these variables used nonparametric statistics: Spearmann's rank–order correlation for correlations between continuous variables, and nonparametric one-way analyses of variance using the median test for categorized variables (SAS, SAS Institute, Cary, North Carolina). Determinants of exposure were explored with logistic regression. Six different data sets were created based on the exposure outcome: all farm operators reporting (1) low (10% of the time or less) and medium (11 to 30% of the time) dust exposure, (2) low and high (more than 30% of the time) dust exposure, (3) low (10% of the time or less) and medium (11 to 39% of the time) noise exposure, (4) low and high (40% of the time or more) noise exposure, (5) low (0 days/year) and medium (1 to 9 days/year) pesticide exposure, and (6) low and high (10 days/year or more) pesticide exposure. Logistic regression models were run using the various data sets with dust, noise, and pesticide exposure as dependent variables and various farm and work characteristics as predictor variables. Initially, models were constructed with only one predictor variable. Second, several predictor variables were evaluated in one model, when appropriate.

TABLE 1. Five Commodities Grown or Raised by the Largest Number of Farm Operators in the Study for the Various Commodity Groupings

Commodity	Number of Farmers (%)	Acres (Median, 25th to 75th Percentile)
Fruit and nuts		
Grapes	385 (19.8)	30 (13–75)
Walnuts	262 (13.5)	14 (4–37)
Almonds	255 (13.1)	30 (10–77)
Oranges	193 (9.9)	10 (3–40)
Peaches	158 (8.1)	5 (2–21)
Field crops		
Pasture land	412 (21.2)	110 (20–900)
Alfalfa for hay	188 (9.7)	98 (40–200)
Oats for hay	126 (6.5)	45 (20–85)
Wheat for grain	101 (5.2)	150 (80–250)
Cotton	81 (4.1)	250 (106–550)
Vegetables		
Tomato, fresh market	60 (3.1)	1 (1–3)
Lettuce	25 (1.3)	25 (1–188)
Tomato, processing	21 (1.1)	250 (110–400)
Onions	21 (1.1)	6 (1–70)
Peppers	19 (1.0)	1 (1–100)
Livestock		
Beef cattle	379 (19.5)	60 (2–210)
Horses	217 (11.1)	4 (2–8)
Diary cows	124 (6.4)	455 (115–975)
Sheep	103 (5.3)	22 (10–52)
Chicken (layers)	69 (3.5)	14 (6–25)
Nursery		
Cut flowers	38 (2.0)	5 (1–16)
Nursery products	37 (1.9)	1 (1–10)
Potted flowers	27 (1.4)	1 (1–3)
Timber	21 (1.1)	160 (25–750)
Christmas trees	13 (0.7)	9 (5–12)

Results

Farm Characteristics

The majority of farm operators grew fruits and/or nuts (63.0%) or field crops (60.1%). Vegetables were grown by 18.0 percent

TABLE 2. Farm and Farm Operator Characteristics by Farming Type

	Overall	Small Mixed	Large mixed	Field	Fruit/Nut	Livestock	Nursery	Vegetables
Farm characteristics								
Number (row %)	1933	246 (12.7)	326 (16.9)	150 (7.8)	864 (44.6)	262 (13.6)	65 (3.4)	20 (1.1)
Number of small farms (%)	789 (40.8)	246 (100.0)	0 (0.0)	32 (21.3)	339 (39.2)	106 (40.5)	46 (70.8)	20 (100.0)
Median acres (25th to 75th percentile)	60 (20–320)	20 (10–63)	500 (192–1530)	371 (148–738)	40 (18–90)	150 (20–1130)	10 (3–35)	18 (6–269)
Farm operator characteristics								
Number of farm operators with farm work ≤20 hours/ week (%)	734 (38.6)	125 (52.1)	36 (11.1)	31 (21.2)	435 (51.5)	88 (34.2)	8 (12.5)	9 (45.0)
No. with nonfarming job (%)	644 (33.1)	126 (51.2)	68 (20.9)	32 (21.3)	321 (37.2)	78 (29.8)	10 (15.4)	7 (35.0)
Start year of farming (median)	1961	1963	1959	1961	1962	1958	1970	1963
No. who used other workers (%)	1245 (63.9)	110 (44.7)	275 (84.8)	93 (62.0)	563 (65.2)	128 (48.9)	58 (89.2)	14 (70.0)
Farm operators with more than half their income from farming (%)	945 (49.2)	53 (21.6)	252 (77.8)	104 (70.3)	346 (40.5)	128 (49.6)	48 (75.1)	11 (57.9)
Median farm hours/ week								
Spring	30	20	60	60	20	35	50	39
Summer	35	24	60	55	25	35	50	40
Fall	30	20	50	50	20	30	40	35
Winter	20	10	40	30	10	30	40	8

Column percentages in parenthesis unless stated.

of the farm operators and livestock was raised by 34.5 percent. A small percentage of the farmers grew nursery products. The five commodities grown or raised by the largest number of farm operators for each commodity grouping are shown in Table 1; grapes, pasture land, tomatoes for the fresh market, beef cattle, and pot flowers topped the various commodity groupings.

The median number of acres was 60 per farm, varying from a median of 10 acres for nursery farms up to a median of 500 acres for large mixed farms (Table 2). Over one-third (39%) of the farm operators spent, on average over the year, 20 or fewer hours per week on farm work. One-third (33%) had a non-farming job, varying from 15 percent of nursery farm operators up to 51 percent of small mixed farm operators. The majority of farm operators (64%) had others doing farm work for them, varying from 45 percent for the small mixed farm operators to 89 percent for the nursery farm operators. Direct-hired labor was the most common type and was reported by 1137 (59%) farm operators. Approximately half of the farm operators got more than half of their total income from farming. The farm operators reported spending fewer hours on farming in the winter compared with other seasons.

Farm Exposures

The median percentages of time that farm operators spent on administration, field supervision, work with livestock, and planting, irrigation, or harvesting showed large differences between various types of farming (Table 3). Half of the farm operators spent about 25 percent of their time on work in the fields, doing planting, irrigating, or harvesting. This varied from 0 percent for livestock farm operators up to 60 percent for field crop operators. The percentages of time working in a noisy or dusty job were divided into quartiles, and for the purpose of presentation the lowest two groups (quartiles) were combined. There were significant differences ($p < 0.01$) in the median percentage of time working in a dusty job and in the percentage of time working in a noisy job between different types of farm operators. Field crop farm operators spent the highest median percentage of their time working in a dusty (30%) and a noisy (20%) job, while nursery farm operators spent the least (median noise, 1%; dust, 0%). The number of dust hours was calculated using the average number of farm hours and the percentage of time working in a dusty job. Field crop farmers had the highest number of dust hours and nursery farmers had the lowest. Field crop farmers also spent more time (median 18%) operating tractors than other types of farm operators. Nursery farm operators spent the least time operating tractors (median 0%).

There was fairly good correlation between percentage of time working in a dusty job and percentage of time working in a noisy job ($r_s = 0.58$). The correlations between the number of pesticide days and the percentage of time working in a noisy

TABLE 3. Farm Exposures Characteristics

	Overall	Small Mixed	Large mixed	Field	Fruit/Nut	Livestock	Nursery	Vegetables
Median (25th to 75th percentile):								
% time administration	10 (5–25)	5 (1–10)	15 (5–40)	12 (5–33)	10 (5–25)	10 (5–20)	25 (10–50)	10 (1–20)
% time field supervision	5 (0–20)	0 (0–10)	10 (1–25)	5 (0–20)	8 (0–25)	0 (0–5)	15 (2–30)	15 (0–40)
% time work with livestock	0 (0–10)	1 (0–40)	7 (0–50)	0 (0–0)	0 (0–0)	60 (30–90)	0 (0–0)	0 (0–0)
% time plant/irrigate/ harvest	25 (2–60)	40 (10–75)	25 (10–50)	60 (25–80)	40 (10–75)	0 (0–0)	20 (0–50)	20 (1–75)
% time construction	6 (0–17)	7 (2–21)	8 (1–18)	9 (1–21)	5 (0–14)	8 (2–19)	2 (0–9)	9 (1–28)
% time M/L/A fertilizer	0 (0–2)	1 (0–4)	0 (0–1)	0 (0–2)	1 (0–3)	0 (0–0)	0 (0–3)	1 (0–5)
% time driving car/ truck	17 (6–38)	10 (3–26)	45 (12–45)	23 (11–40)	15 (5–37)	19 (8–39)	10 (4–25)	21 (9–83)
% time driving tractor	10 (0–31)	12 (1–32)	12 (2–32)	18 (5–61)	12 (0–35)	2 (0–12)	0 (0–6)	4 (0–28)
Farm dust hours* (hours/week)	2.6 (0.2–9.0)	2.1 (0.2–6.8)	4.1 (1.2–13.5)	6.3 (2.4–21.21)	2.2 (0.2–8.0)	1.3 (0.0–6.0)	0 (0.0–3.0)	5.1 (0.5–13.4)
% time outdoors	75 (50–90)	80 (50–95)	70 (50–80)	75 (50–90)	75 (50–90)	75 (50–90)	50 (10–80)	55 (35–80)
Categorized:								
10% time noise or less	1051 (54.9)	141 (51.6)	163 (50.8)	42 (29.0)	432 (50.7)	206 (80.4)	49 (76.6)	9 (47.4)
11–39% time noise	407 (21.3)	48 (19.6)	87 (27.1)	40 (27.6)	187 (22.0)	30 (11.7)	8 (12.5)	6 (31.6)
40% or more time noise	456 (23.8)	56 (22.9)	71 (22.1)	63 (43.5)	233 (27.4)	20 (7.8)	7 (10.9)	4 (21.1)
10% time dusty job or less	1102 (57.4)	138 (56.4)	191 (59.1)	63 (42.8)	454 (53.1)	182 (71.6)	52 (82.6)	10 (50.0)
11–30% time dusty job	398 (20.7)	54 (22.0)	79 (24.5)	33 (22.5)	185 (21.6)	38 (15.0)	4 (6.4)	4 (20.0)
30% or more time dusty job	421 (21.9)	53 (21.6)	53 (16.4)	51 (34.7)	216 (25.3)	34 (13.4)	7 (11.1)	6 (30.0)
0 pesticide days/year	1046 (54.1)	129 (52.7)	190 (58.6)	91 (61.5)	375 (43.7)	211 (81.2)	27 (43.6)	14 (70.0)
1–9 pesticide days/ year	455 (23.6)	82 (33.5)	53 (16.4)	29 (19.6)	238 (27.7)	35 (13.5)	12 (19.4)	4 (20.0)
10 pesticide days/ year or more	431 (22.3)	34 (13.9)	81 (25.0)	28 (18.9)	246 (28.6)	14 (5.4)	23 (37.1)	2 (10.0)

*Estimated using the percentage time working in a dusty job and the average number of farm hours.

job or the percentage of time working in a dusty job were lower, 0.29 and 0.24, respectively.

Less than half of all farm operators (45.9%) mixed, loaded, or applied pesticides, varying from 18.8 percent for livestock farm operators up to 56.3 percent for fruit and nut farm operators. The percentage of farm operators that mixed, loaded, or applied pesticides for 10 days or more varied from 5.4 percent for livestock farm operators up to 37.1 percent for nursery farm operators.

There were significant differences ($p < 0.01$) in the percentage of time working in a dusty and noisy job between different regions. The highest percentages of time working in a dusty or a noisy job were reported by farm operators from the Sacramento Valley and San Joaquin Valley and the lowest by farm operators from the southern California region.

Protective Equipment

Among farm operators who reported work in a noisy job, the majority (57.8%) never wore any ear protection during work in a noisy job. Forty-three percent of farm operators who reported work in a dusty job never wore any dust protection (for example, dust mask, cartridge, or scarf) while working in a dusty job. During work in a dusty job, the most frequently reported piece of personal protective equipment was a dust mask.

The large majority of farm operators (93.0%) used some kind of protection during work with pesticides. Gloves were the most frequently reported piece of personal protective equipment during work with pesticides (Tables 4 and 5). Approximately one-third (34.3%) of the farm operators reported wearing all forms of protective equipment (gloves, protective cloths, a cartridge respirator, a face shield or goggles, and rubber boots) for some time during mixing, loading, and application of pesticides. Overall, livestock farmers most frequently reported not wearing any personal protective equipment when working in a dusty or noisy job or with pesticides. Field crop farm operators more often had a cabin on the tractor than any other type of farm operators.

TABLE 4. Number of Farm Operators (%) Who Use Ear and Dust Protection During Work in a Noisy Job (n = 1564 Farm Operators) or Dusty Job (n = 1490 Farm Operators), Respectively

	Overall	Small Mixed	Large Mixed	Field	Fruit	Livestock	Nursery	Vegetables
Ear protection								
Never	898 (57.8)	103 (51.8)	181 (60.9)	65 (47.5)	397 (56.1)	122 (72.6)	16 (48.5)	12 (75.0)
<50% time	199 (12.7)	25 (12.6)	36 (12.1)	19 (13.9)	102 (14.4)	12 (7.1)	4 (12.1)	0 (0.0)
50% of time or more	467 (29.9)	71 (35.7)	80 (27.0)	53 (38.7)	209 (29.5)	34 (20.3)	13 (39.4)	4 (25.1)
Dust mask								
Never	753 (50.5)	100 (51.6)	150 (55.0)	77 (58.3)	270 (40.7)	125 (71.8)	14 (48.3)	13 (76.5)
<50% time	296 (19.9)	48 (24.7)	60 (22.0)	23 (17.4)	134 (20.2)	26 (14.9)	3 (10.3)	1 (5.9)
50% of time or more	441 (29.6)	46 (23.8)	63 (23.1)	32 (24.3)	260 (39.3)	23 (13.2)	12 (41.4)	3 (17.6)
Cartridge respirator								
Never	1259 (84.5)	175 (90.2)	234 (86.0)	112 (84.9)	528 (79.5)	168 (96.6)	23 (76.7)	14 (82.4)
<50% time	159 (10.7)	12 (6.2)	32 (11.8)	14 (10.6)	91 (13.7)	3 (1.7)	5 (16.7)	2 (11.7)
50% of time or more	72 (4.9)	7 (3.6)	6 (2.2)	6 (4.6)	45 (6.8)	3 (1.8)	2 (6.6)	1 (5.9)
Scarf								
Never	1224 (82.1)	155 (79.9)	223 (81.7)	108 (81.2)	549 (82.8)	144 (82.8)	24 (80.0)	14 (82.4)
<50% time	153 (10.3)	20 (10.3)	30 (11.0)	15 (11.4)	63 (9.5)	20 (11.5)	3 (10.0)	2 (11.8)
50% of time or more	113 (7.6)	19 (9.8)	20 (7.3)	33 (6.8)	51 (7.7)	10 (5.8)	3 (10.0)	1 (5.9)
No cabin*	1168 (81.3)	188 (96.9)	159 (59.8)	49 (39.5)	586 (90.8)	145 (90.6)	27 (90.0)	10 (83.3)
Cabin present*	269 (18.7)	6 (3.1)	107 (40.2)	75 (60.5)	59 (9.2)	15 (9.4)	3 (10.0)	2 (16.7)

*Cabin on primary tractor.

There was no increase in the use of dust masks with an increase in the percentage of time working in a dusty job (Table 6). There were slight increases in the use of ear plugs or muffs with an increase in the percentage of time working in a noisy job. There was a larger increase in the use of cartridge respirators with an increase in the number of pesticide days.

Determinants of Dust, Noise, and Pesticide Exposure

Logistic regression models with dust, noise, or pesticide exposure, respectively, as dependent variable and one single predictor variable are shown in Table 7. Significantly elevated odds ratios were observed for the percentage of time working outdoors, driving a tractor, working in the field, carrying out

TABLE 5. Number of Farm Operators (%) Who Use Protection During Mixing, Loading, and Application of Pesticides

	Overall	Small Mixed	Large Mixed	Field	Fruit	Livestock	Nursery	Vegetables
Gloves								
Never	137 (15.5)	23 (19.8)	16 (11.9)	4 (7.0)	75 (15.5)	16 (32.7)	1 (2.9)	1 (16.7)
<50% time	30 (3.4)	4 (3.5)	5 (3.7)	1 (1.8)	16 (3.3)	3 (6.1)	1 (2.9)	0 (0.0)
50% of time or more	719 (81.2)	89 (76.7)	113 (84.3)	52 (91.2)	393 (81.2)	30 (61.2)	33 (94.3)	5 (83.3)
Clothes								
Never	242 (27.4)	47 (40.5)	32 (24.1)	21 (36.8)	104 (21.5)	29 (60.4)	6 (17.1)	1 (16.7)
<50% time	44 (5.0)	7 (6.0)	9 (6.8)	0 (0.0)	22 (4.6)	2 (4.2)	3 (8.6)	0 (0.0)
50% of time or more	598 (67.6)	62 (53.5)	92 (69.2)	36 (63.2)	358 (74.0)	17 (35.4)	26 (74.3)	5 (83.3)
Cartridge respirator								
Never	389 (44.1)	64 (55.2)	58 (43.6)	30 (52.6)	185 (38.4)	42 (85.7)	7 (20.0)	1 (16.7)
<50% time	95 (10.8)	6 (5.2)	14 (10.5)	10 (17.5)	61 (12.7)	0 (0.0)	3 (8.6)	1 (16.7)
50% of time or more	399 (45.2)	46 (39.7)	61 (45.9)	17 (29.8)	236 (49.0)	7 (14.3)	25 (71.4)	4 (66.7)
Rubber boots								
Never	345 (39.1)	51 (44.0)	44 (33.1)	27 (47.4)	183 (38.0)	24 (49.0)	11 (31.4)	3 (50.0)
<50% time	92 (10.4)	12 (10.3)	17 (12.8)	1 (1.8)	50 (10.4)	9 (18.4)	1 (2.9)	1 (16.7)
50% of time or more	446 (50.2)	53 (45.7)	72 (54.1)	29 (50.9)	249 (51.7)	16 (32.7)	23 (65.7)	2 (33.3)
Face shield/goggles								
Never	255 (28.8)	51 (44.0)	32 (24.1)	13 (22.8)	120 (24.8)	28 (57.1)	7 (20.0)	3 (50.0)
<50% time	60 (6.8)	3 (2.6)	9 (6.8)	3 (5.3)	37 (7.7)	5 (10.2)	2 (5.7)	1 (16.7)
50% of time or more	569 (64.4)	62 (53.5)	92 (69.2)	41 (71.9)	326 (67.5)	16 (32.7)	26 (74.3)	2 (33.3)

TABLE 6. Percentage of Time Working in a Dusty, Noisy Job and the Number of Days Working with Pesticides Against the Percentage of Time Farm Operators Wear Protective Equipment

		Never	Up to 50%	50% or more	Total
Percentage of time wearing dust mask					
% of time in dusty job	1–10%	353 (52.6)	122 (18.2)	196 (29.2)	871 (100.0)
	11–30%	193 (48.5)	82 (20.6)	123 (30.9)	398 (100.0)
	More than 30%	207 (49.2)	92 (21.9)	122 (29.0)	421 (100.0)
Percentage of time wearing ear plugs or muffs					
% of time in noisy job	1–10%	454 (64.7)	72 (10.3)	175 (25.0)	701 (100.0)
	11–39%	221 (54.3)	52 (12.8)	134 (32.9)	407 (100.0)
	40% or more	223 (48.9)	75 (16.4)	158 (34.7)	456 (100.0)
Percentage of time wearing cartridge respirator					
No. of pesticide days	1–9	245 (54.0)	38 (8.4)	171 (37.7)	454 (100.0)
	10 or more	144 (33.6)	57 (13.3)	228 (53.2)	429 (100.0)

field supervision, and performing construction or repair of buildings or equipment, implying that they are associated with a larger percentage of time working in dusty jobs (Table 7). For example, for dust exposure, the odds ratio was 1.25 for every 10 percent reported increase in tractor driving when the data set with those who reported low (10% or less of the time in a dusty job) and medium (11 to 30% of the time in a dusty job) dust exposure was used. The odds ratio was 1.28 when using the data set with those who reported low (10% or less of the time in a dusty job) and high (>30% of the time) dust exposure. Significantly reduced odds ratios were observed for the percentage of time working with livestock and for large farms compared with small farms. There was no significant association between the presence of an enclosed cabin on the tractor and exposure to dust, pesticides, or noise. A logistic regression model including all these predictor variables was not attempted because of the moderate correlation among them (Table 8). For those variables that were not correlated, models with several predictor variables showed similar results to the models with a single predictor variable.

To determine the influence of region or farm type on the self-reported exposures, logistic regression models with dust, noise, and pesticides as dependent variables, respectively, and farm type or region as one single predictor were run (for example, one region compared with another region or one farming type compared with another). These showed similar results as logistic regression models with multiple predictors (region and farming type, Table 9).

The models with dust or noise exposure as dependent variables showed similar results (Table 9). Vegetable, fruit and nut, field crop, nursery (only for one noise exposure category), and mixed farmers had significantly elevated odds ratios for dust and noise exposure compared with livestock farm operators, indicating more self-reported exposure. In particular, field crop farmers reported more time in dusty and noisy jobs compared with livestock farmers. For example, for dust expo-

TABLE 7. Odds Ratios from Logistic Regression Models with Dust, Noise, and Pesticide Exposure as Dependent Variables, Respectively, and Selected Work Characteristics as Single Predictor Variables

Percentage of Time	Data Set	Dust Odds Ratio (CI)	Noise Odds Ratio (CI)	Pesticide Odds Ratio (CI)
Working outdoors	Low versus medium	1.16 (1.11–1.21)	1.16 (1.11–1.21)	1.11 (1.06–1.15)
	Low versus high	1.24 (1.19–1.30)	1.28 (1.23–1.34)	1.13 (1.09–1.18)
Working in the field	Low versus medium	1.13 (1.09–1.18)	1.17 (1.13–1.22)	1.16 (1.12–1.20)
	Low versus high	1.22 (1.17–1.26)	1.28 (1.24–1.33)	1.19 (1.15–1.24)
Working with livestock	Low versus medium	0.98 (0.94–1.02)	0.91 (0.87–0.95)	0.89 (0.85–0.93)
	Low versus high	0.95 (0.91–0.99)	0.86 (0.82–0.90)	0.77 (0.72–0.82)
Field supervision	Low versus medium	1.11 (1.05–1.17)	1.09 (1.03–1.15)	1.07 (1.02–1.13)
	Low versus high	1.08 (1.03–1.14)	1.09 (1.04–1.15)	1.21 (1.15–1.28)
Tractor driving	Low versus medium	1.25 (1.20–1.31)	1.29 (1.22–1.35)	1.07 (1.03–1.12)
	Low versus high	1.28 (1.22–1.33)	1.45 (1.38–1.52)	1.13 (1.09–1.18)
Construction/repair	Low versus medium	1.11 (1.04–1.17)	1.10 (1.04–1.17)	1.06 (1.00–1.11)
	Low versus high	1.15 (1.09–1.21)	1.14 (1.08–1.20)	1.05 (0.99–1.12)
Mix/load/apply fertilizer	Low versus medium	1.07 (0.94–1.21)	1.07 (0.94–1.22)	1.26 (1.10–1.45)
	Low versus high	1.14 (1.00–1.28)	1.17 (1.05–1.32)	1.36 (1.17–1.57)
Large farm compared with small farm	Low versus medium	0.62 (0.49–0.79)	0.75 (0.59–0.94)	1.03 (0.82–1.28)
	Low versus high	0.77 (0.61–0.96)	0.57 (0.46–0.73)	0.43 (0.36–0.59)

Odds ratios are per 10 percentage points increase in the predictor variable except for the farm size, where large farms are compared with small farms.
CI = 95% confidence intervals.

TABLE 8. Spearman Correlation Coefficients for Various Work Characteristics

	Percentage of Time			
Percentage of Time	**In the Field**	**Livestock**	**Supervising**	**Tractor Driving**
Working outdoors	0.36*	0.07*	−0.04	0.24*
Working in the field		−0.34*	0.02	0.41*
Working with livestock			−0.23*	−0.04
Supervising				−0.05*
Construction/repair	0.19*	0.14*	0.04	0.38*
Operate car/truck	−0.10*	0.02	0.20*	0.02
Mix/load/apply fertilizer	0.40*	−0.24*	0.13*	0.34*

*$p < 0.05$.

sure the odds ratio was 2.3 when the data set with those who reported low (10% or less of the time in a dusty job) and medium (11 to 30% of the time in a dusty job) dust exposure was used, indicating that field crop farmers were 2.3 times more likely to report medium dust exposure than livestock farmers. The odds ratio was 4.2 when the data set with those who reported low (10% or less of the time in a dusty job) and high (>30% of the time) dust exposure was used, indicating that field crop farmers were 4.2 times more likely to report high dust exposure than livestock farmers. Significantly elevated odds ratios were observed for other California regions compared with the southern California region. The models with pesticide exposure as the dependent variable gave different results. The nursery farm category showed the highest pesticide exposure. The north coast and mountain regions showed slightly lower pesticide exposure than the southern California region, although this was not significant.

Discussion

This article describes the self-reported exposure to dust, noise, and pesticides in a statewide random sample of California farm operations. The sample confirms the enormous diversity in California agriculture. There were considerable differences in exposure between various types of farming, and smaller differences between regions. Field crop farmers reported the highest percentage of time working in dusty or noisy jobs, and nursery farmers reported the largest number of days with pesticide exposure. Farm operators from the Sacramento and San Joaquin Valleys were among those who reported the highest exposure to dust, noise, and pesticides. One of the strongest and most plausible predictors of the exposure to dust and noise was the percentage of time driving a tractor. Overall, farm operators with small farms reported more exposure to dust,

TABLE 9. Odds Ratios from Logistic Regression Models with Dust, Noise, and Pesticide Exposure, Respectively, as Dependent Variables, and Farm Category and Region as Multiple Predictor Variables

	Data Set	Dust Odds Ratio (CI)	Noise Odds Ratio (CI)	Pesticide Odds Ratio (CI)
Farm category[A]				
Vegetables	Low versus medium	2.1 (0.6–7.0)	4.7 (1.6–14.4)	1.7 (0.5–5.5)
	Low versus high	3.0 (1.0–9.1)	5.2 (1.4–19.0)	2.0 (0.4–9.6)
Small mixed	Low versus medium	1.9 (1.2–3.1)	2.5 (1.5–4.2)	4.0 (2.6–6.4)
	Low versus high	2.3 (1.4–3.7)	4.7 (2.7–8.2)	4.2 (2.2–8.2)
Nursery	Low versus medium	0.5 (0.2–1.5)	1.5 (0.7–3.6)	3.7 (1.7–8.2)
	Low versus high	1.2 (0.4–2.6)	2.7 (1.1–7.0)	18.7 (8.4–42.1)
Fruit and nut	Low versus medium	2.0 (1.4–3.1)	3.3 (2.2–5.2)	3.6 (2.4–5.4)
	Low versus high	2.4 (1.6–3.7)	5.9 (3.6–9.8)	9.0 (5.1–16.0)
Field crop	Low versus medium	2.3 (1.3–4.0)	6.5 (3.6–11.8)	1.7 (1.0–3.0)
	Low versus high	4.2 (2.5–7.2)	15.5 (8.3–28.8)	4.3 (2.1–8.7)
Large mixed	Low versus medium	1.9 (1.2–3.0)	3.8 (2.4–6.2)	1.6 (1.0–2.6)
	Low versus high	1.4 (0.9–2.3)	4.6 (2.6–7.9)	6.3 (3.4–11.6)
Region[B]				
North Coast	Low versus medium	3.4 (1.7–6.9)	2.4 (1.1–5.4)	0.9 (0.4–2.1)
	Low versus high	2.4 (1.0–5.7)	7.5 (3.5–16.3)	0.9 (0.4–2.2)
Central Coast	Low versus medium	1.7 (1.1–2.7)	2.6 (1.7–4.1)	1.7 (1.1–2.6)
	Low versus high	2.7 (1.7–4.4)	3.8 (2.2–6.5)	2.4 (1.5–3.8)
Sacramento Valley	Low versus medium	2.7 (1.7–4.1)	3.3 (2.1–5.1)	2.5 (1.6–3.8)
	Low versus high	3.1 (1.9–5.0)	6.3 (3.8–10.4)	2.7 (1.7–4.2)
San Joaquin Valley	Low versus medium	2.1 (1.4–3.0)	2.2 (1.5–3.3)	2.2 (1.5–3.1)
	Low versus high	3.4 (2.3–5.0)	5.2 (3.3–8.1)	2.6 (1.8–3.8)
Mountain	Low versus medium	1.9 (1.1–3.4)	2.1 (1.1–3.9)	1.3 (0.7–2.3)
	Low versus high	1.6 (0.8–3.2)	4.0 (2.1–7.8)	0.7 (0.3–1.6)

[A]Farming types are compared to the livestock category.
[B]Regions are compared to the Southern California region.
CI = 95% confidence interval.

noise, and pesticides than those from large farms. Farm operators were more likely to wear personal protection with an increase in exposure to pesticides and noise but not with an increase in exposure to dust. These findings identify farm operators at higher risk of hazardous agricultural exposures in California, and can be used for epidemiological studies of disease incidence and to set priorities for preventive efforts in health and safety.

Exposure assessment in agriculture is difficult because of the varied and cyclic nature of the farmers' work and the diverse locations of the farms. Monitoring of exposures is rarely done, and if done, it is done only on a small scale and on a limited number of commodities.[1–8] Self-reported exposure has been used instead. Reports have shown that workers are able to estimate their occupational exposure with reasonable success.[21–26] In this study we used the self-reported exposures mainly for comparison between various categories such as types of farming. It was assumed that farm operators from one farming type would not interpret the questions differently than operators from another farming type and thereby create a bias. There is a need, however, to validate these self-reported exposures, and currently we are undertaking such a study.

Field crop farming and tractor driving were associated with a higher exposure to dust and noise. Field crop farm operators reported the highest percentage of time driving a tractor. The self-reported dust and noise exposure showed fairly good correlation. This is in agreement with previous reports that have reported high exposure to dust and noise during these operations.[2,5,27,28] For example, Louhelainen *et al.*[2] reported mean dust concentrations of 18 mg/m^3 during rolling operations, and Holt *et al.*[5] reported that 75 percent of the tractors without a cabin had noise levels over 90 dB. Reported dust and noise levels were considerably lower when there was a closed cabin on the tractor.[5,28] In this study we found no association between self-reported exposure to dust, noise, and pesticides and the presence of a closed cabin on the tractor. This might be explained by the small number of closed cabins, and because there was no information on how they were used.

In this study there were several predictors for the exposures, such as percentage of time working outdoors, percentage of time working in the field, and percentage of time driving a tractor. Several variables were correlated, and this might explain why some were significant predictors of the exposures. In cases such as these it must be decided which are the most plausible predictors. This also might be true for the various regions. Although there are differences in climate which might explain the differences in dust exposure between regions, the distribution of farming types also differs between regions, and this might explain some of the differences in exposure between the various regions. For example, the San Joaquin Valley and the southern California regions had the highest and lowest reported dust exposure, respectively. At the same time they also had the highest and the second lowest percentage of field crop farmers, respectively.

Farm operators were more likely to wear personal protection with an increase in exposure to pesticides and noise, but not with an increase in exposure to dust. An explanation for this might be the greater emphasis on legislation and education associated with pesticide and noise exposure as compared with dust exposure. In particular, pesticides are perceived to be more hazardous and related to illness than dust. Often farm operators are not aware of the illnesses related to dust. Education could change their perception and increase understanding.

These results could be used to set priorities in agricultural health and safety. They give an indication of where illnesses are most likely to occur. More in-depth studies are necessary to evaluate the exposures in more detail. For example, for this study dust was regarded as one exposure, although in fact it has various constituents such as inorganic quartz, organic allergens, or endotoxins, which can cause different illnesses.

Acknowledgments

This work was supported by the National Institute for Occupational Safety and Health, Cooperative Agreement U07/CCU906162-05, and the National Institute for Environmental Health Science, center grant 1 P30 ES05707.

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