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Human Exposure to Poultry and Poultry Products and the Risk of Death from Hematopoietic & Lymphatic Cancers

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Authors' contributions

This work was carried out in collaboration between all authors. Author ESJ designed and obtained funding for the study, supervised all aspects of data collection, wrote the protocol, participated in the statistical analysis and writing the manuscript. Author SB was involved in data collection and tracing of study subjects, conducted telephone interviews, was primarily responsible for the statistical analysis of the data and participated in writing the manuscript. Author MJF supervised all aspects of data collection and statistical analysis of the data and participated in writing the manuscript. All authors read and approved the final manuscript.

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Short Communication

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ABSTRACT

Purpose: The purpose of this study was to obtain preliminary information on occupational exposures responsible for the excess of hematopoietic & lymphatic (H&L) cancers previously observed in cohort mortality studies of workers in poultry slaughtering and processing plants.
Methods: A pilot case-cohort study was conducted nested within a combined cohort of 30,411

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poultry workers and 16,408 controls, identified from several United Food & Commercial Workers (UFCW) unions across the United States. Interviewed cases were 48 deaths out of a total of 130 deaths (37%) from H & L tumors that occurred in the cohort between 1990-2003. Controls were N=152 subjects that were successfully interviewed out of 1516 subjects (10%) randomly selected from all cohort members alive as of January 1, 1990. Telephone interviews were obtained directly from live control subjects or next-of-kin for deceased cases and controls. Mortality risk was assessed using logistic regression odds ratios and hazard ratios.

Results: Poultry farming [OR=10.8 (95% CI: 3.0-39.1)] and spreading chicken wastes as manure [OR=5.6 (95% CI: 1.5-20.4)] were significantly associated with lymphoma; handling raw eggs in supermarkets [OR=4.3 (95% CI: 1.0-18.0)] was significantly associated with leukemia. Non-poultry exposures significantly associated with these tumors included coal by-products, selling seafood, and killing of pigs.

Conclusion: This preliminary study identifies possible occupational exposures that may be associated with excess deaths from H & L tumors in poultry workers. Case-control studies of sufficient statistical power are now needed to confirm these findings and discover new ones.

Keywords: Chicken plants; leukemia; lymphoma; poultry; cancer; occupational exposures; mortality.

ABBREVIATIONS

ALSV : Avian Leukosis/Sarcoma Viruses.
CI : Confidence Interval.
H & L : Hematopoietic and Lymphatic Cancers.
HPV : Human Papilloma Virus.
HR : Hazard Ratios.
IACR : International Association of Cancer Research.
ICD : International Classification of Diseases.
MDV : Marek's Disease Virus.
OR : Odds Ratio.
PAHs : Polycyclic Aromatic Hydrocarbons.
REV : Reticuloendotheliosis Viruses.
SAS : Statistical Analysis System.
UFCW : United Food and Commercial Workers Union.

1. INTRODUCTION

Workers in poultry slaughtering and processing plants perform a variety of tasks, ranging from unloading live birds from trucks when they arrive at the plant, to shackling, killing, scalding, eviscerating, chilling, further processing, packing, storing in the cold room, and loading processed products into trucks for delivery to retail establishments [1]. In the process, the workers come into contact with the blood, internal organs, secretions, and skin of thousands of chickens daily. In some plants, up to 175,000 chickens are killed each day. This brings them into intimate contact with poultry blood, organs, and secretions. Frequent cuts and injuries from sharp knives and bone splinters provide a portal of entry for microorganisms to enter the body through the skin [2]. Additional hazards to workers include airborne transmission of microbial agents that also occurs in poultry plants [3].

Oncogenic viral exposures in poultry plants include viruses such as avian leukosis/sarcoma viruses (ALSV), reticuloendotheliosis virus (REV), and Marek's disease virus (MDV), all of which have been shown to cause hematopoietic and lymphatic (H & L) cancers in poultry [4]. Also, poultry workers are known to have a high prevalence of warts caused by human papilloma viruses (HPV) [5,6].

Humans are widely exposed to these viruses. What remains unknown is whether ALSV, REV and MDV can also cause cancer in humans. The literature examining the health risks due to occupational exposures among workers in poultry slaughtering and processing plants has shown excess mortality risks for H & L cancers [7-12]. *In vitro* experiments have revealed that these viruses can infect and cause malignant transformation in human cells [13]. In addition, some studies have reported the presence of antibodies to all of these viruses in the sera of poultry workers and in general population subjects [14-16], while others have not [17]. The workers are also potentially exposed to chemical carcinogens at work. This paper attempts to provide preliminary data for the first time, on which specific occupational exposures in poultry slaughtering and processing plants may be candidates to explain the reported increased mortality due to these cancers among poultry workers.

2. MATERIALS AND METHODS

The source population consisted of the 30,411 workers in poultry slaughtering and processing plants, and 16,405 non-poultry workers (miscellaneous group of seafood plants; Canned meat, soups and vegetable plants; Soft drinks

manufacturing plants; Salad, margarine and mayonnaise plants; fertilizer and seeds plants; Trucking industry; etc.), for a total of 46,816 subjects who were members of the United Food and Commercial Workers Union (UFCW) unions between 1949 and 1989, in the United States. The workers were from unions located in 15 states. Among this group, 2,915 had died by the end of 1989. The remaining 43,904 subjects that were alive as of January 1, 1990 constituted the base population that was followed up from January 1, 1990 until December 31, 2003, using a variety of methods that include the National Death Index, Pension Benefit Information Inc., Social Security Administration, State Departments of Vital Records, Maryland State Department of Motor Vehicle, Health Care Financing Administration, Veterans Administration, Equifax, US Postal Services, Obituary Notices, and telephone directories. Since no new subjects were added after January 1, 1990, and all subjects lost to follow-up were assumed to be alive at the end of the study, the group of subjects alive as of January 1, 1990 was essentially a closed cohort.

Cases were defined as deaths from all types of H & L cancers (ICD, Ninth Revision, codes 200, 202-208; or ICD Tenth Revision, codes C82-C96) that occurred in the base population between January 1, 1990, and December 31, 2003 (N=130). The comparison group was a subcohort that consisted of 1,516 live subjects randomly sampled from the base population, some of whom later died during the study period.

Because this was a pilot study, exhaustive attempts were not made to trace study subjects or their next-of-kin. Thus, we report here on the first 48 deaths (37%) from H & L cancers (cases) whose next-of-kin were traced, and completed a telephone interview that provided information on the deceased cases within the limited time available to do the study. Similarly, we report on the first 152 members of the subcohort (10%) for whom an interview was obtained either directly if the subject was alive, or from the next-of-kin if the subject was deceased.

The questionnaire was administered to the next-of-kin of deceased study subjects, or to the subject himself or herself if alive, using a computer-assisted telephone software (Questionnaire Development System, NOVA Research Company, Bethesda, Maryland). It contained over 600 questions on occupational poultry specific exposures, history of exposures at work (non-poultry related), medical history, medications, lifestyle, immunizations, and diet, that were intentionally broadly framed to facilitate recall. The questionnaire took an average of 40–60 minutes to complete. Risk associated with each job exposure was calculated for “ever/never” responses. Dates and duration of working at each task are not presented because of sparse data.

To obtain information on the reliability of responses from proxies, the questionnaire was administered to a small subset of seven pairs of live control study subjects and their next-of-kin.

Baseline data from cases and controls were compared using chi-square tests. Odds ratios (ORs) and 95% confidence intervals (95% CI) were estimated using unconditional logistic regression (SAS 9.1, SAS Institute, Cary, NC). Since time-to-event information was available, a Cox regression analysis was used to estimate hazard ratios (HR) and 95% CI. Failure time for formation of a risk set was the difference between age at study entry (January 1, 1990) and age at time of a case-related death. At failure time, a risk set was formed consisting of the case and all available controls at risk at that time. All failures were included, regardless of whether they occurred in the sub-cohort or not. A case outside of the subcohort was not at risk until just before its failure, and therefore was not included in the earlier risk sets. All variables were tested to determine whether they satisfied the proportional hazards assumptions. Risk estimates were adjusted for both categorical age and union status (Chicago, Baltimore, and Missouri). Analyses of poultry and non-poultry occupational exposures were performed across all H & L histologic subtypes in aggregate. Exploratory analyses were further conducted when possible across specific H & L types (leukemia, lymphoma, and multiple myeloma).

3. RESULTS

Of the first 61 cases who died from cancer of the H & L systems whose next-of-kin were traced, interviews were obtained for 48 (79%) within the limited time available to do the study. Similarly, of the first 214 subjects in the subcohort (n = 1,516) or their next-of-kin that were traced during the time available, 152 (71%) completed phone interviews with the same questionnaire either directly (if alive), or through their next-of-kin if deceased. None of the interviewed cases were members of the subcohort control group.

The limited comparison that was performed on exposure information provided by seven pairs of

live control study subjects with their respective next of kin indicated that of the 245 direct responses obtained for dichotomous questions, there was an agreement of 80% to 100% between the pairs for nearly 75% of the responses, with less than 60% agreement for only 8% of the responses.

Baseline demographic information on interviewed cases and controls are given in Table 1.

The results obtained by logistic regression and by Cox regression analyses were similar (Table 2). Histologic subtype analyses results for leukemia and lymphoma for the four poultry exposures with elevated ORs for all H & L tumors combined are given in Table 3.

In Table 4, risk estimates are given for potentially carcinogenic exposures in poultry plants other than oncogenic viruses.

The risk estimates for non-poultry occupational exposures are provided in Tables 5 and 6.

4. DISCUSSION

In Table 1, interviewed cases were similar to all cases, and interviewed controls were similar to the subcohort for demographic variables. The differences in ages between cases and controls are expected since controls were a random sample of the cohort. Accordingly, we adjusted for age, for which there was a significant difference. We also adjusted for union status because geographic variability in unknown factors may affect the results, especially as the Missouri cohort was all poultry and did not have subjects outside the poultry industry. Because of sparsity of the data, we could not adjust for race.

Table 1. Baseline demographic distribution of interviewed cancer cases and controls in the combined cohort of poultry and non-poultry United Food & Commercial Workers Union Workers, USA, 1990-2003

Characteristic	Total cases in cohort N= 130	Interviewed cases N = 48	Selected controls subcohort N=1,516	Interviewed controls N = 152
Race				
White	97 (75%)	42 (88%)	NA	108 (80%)
Black	33 (25%)	3 (6%)	NA	27 (20%)
Unknown	0	3 (6%)	NA	17
Total	130	48	1,516	152
Gender				
Female	72 (55%)	24 (50%)	785 (52%)	87 (58%)
Male	58 (45%)	24 (50%)	723 (48%)	64 (42%)
Unknown	0	0	8	1
Total	130	48	1,516	152
Age years				
<50	24 (18%)	9 (19%)	1061 (72%)	103 (68%)
≥ 50	106 (82%)	39 (81%)	413 (28%)	48 (32%)
Unknown	0	0	42	1
Total	130	48	1,516	152
Type of worker				
Poultry	82 (63%)	32 (67%)	898 (59%)	118 (78%)
Non-poultry	48 (37%)	16 (33%)	618 (31%)	34 (22%)
Total	130	48	1,516	152
Union status				
Chicago	81 (62%)	35 (74%)	925 (61%)	113 (75%)
Missouri	29 (22%)	5 (10%)	308 (20%)	36 (24%)
Baltimore	20 (15%)	7 (15%)	283 (19%)	2 (1%)
Unknown	0	1	0	1
Total	130	48	1,516	152

**Cases (age at death); Control (age at 2003). Information on race for controls was only available for those interviewed*

Table 2. Adjusted risk estimates for poultry occupational tasks/exposures - all deaths from hematopoietic and lymphatic tumors combined (1990- 2003)

Exposure	Adjusted OR† (95% CI)	Adjusted HR† (95% CI)
Smoking poultry at work	3.1 (0.4 - 22.3)	3.1 (0.4 - 24.3)
Worked as a poultry farmer	3.1 (1.0 - 9.6)#	2.4 (1.0 - 5.6)#
Spread chicken/bird wastes as manure	2.0 (0.6 - 6.9)	2.6 (1.1 - 6.1)*
Handle raw eggs in grocery stores or supermarkets	2.2 (0.1 - 9.8)	1.6 (0.7 - 3.8)
Work in a place where chicken/bird feathers were handled	1.4 (0.5 - 3.8)	1.7 (0.5 - 5.4)
Had direct contact with poultry blood	1.4 (0.7 - 3.0)	1.1 (0.6 - 2.1)
Killed chickens/birds at work	1.4 (0.3 - 7.1)	1.1 (0.3 - 4.6)
Work in a plant where poultry was slaughtered	1.1 (0.4 - 3.5)	1.1 (0.6 - 2.1)
Contact or handle raw poultry at work	0.6 (0.3 - 1.3)	0.6 (0.3 - 1.1)
Wrap raw chicken/birds at work	0.6 (0.2 - 1.4)	0.5 (0.3 - 1.2)

OR = Odds ratios; HR = Hazard ratios; CI = Confidence intervals.
† adjusted by age and union status
** Statistically significant at the 95% confidence level; # Borderline statistically significant at the 95% confidence level*

Table 3. Adjusted odds ratios for Poultry occupational tasks/exposures by histologic subtype of hematopoietic and lymphatic cancers, 1990-2003

Exposure	Lymphoma Adjusted OR† (95% CI)	Leukemia Adjusted OR† (95% CI)
Smoking poultry at work	4.2 (0.4 - 43.0)	3.0 (0.3-30.3)
Worked as a poultry farmer	10.8 (3.0 - 39.1)*	-
Spread chicken/bird wastes as manure	5.6 (1.5 - 20.4)*	-
Handled raw eggs in grocery stores or supermarkets	-	4.3 (1.0-18.0)*

*OR = Odds ratio; CI = Confidence interval. *Statistically significant at the 95% confidence level*
† adjusted by age and union status

Table 4. Adjusted risk estimates for specific potentially carcinogenic exposures in poultry slaughtering and processing plants other than oncogenic viruses – all deaths from hematopoietic and lymphatic tumors combined (1990- 2003)

Carcinogenic exposures other than oncogenic viruses	Adjusted OR† (95% CI)	Adjusted HR† (95% CI)
Smoking poultry at work (PAH)	3.1 (0.4-22.3)	3.1 (0.4-24.3)
Curing meat at work (nitrosamines)	0.7 (0.1-6.4)	0.6 (0.1-4.6)
Wrap chicken using a wrapping machine (benzene, PAH, phthalates)	0.6 (0.2-2.0)	0.6 (0.2-1.9)
Cooked poultry partly or wholly (PAH, heterocyclic amines)	0.4 (0.1-1.6)	0.5 (0.2-1.7)
Exposure to aflatoxin	---	---

OR = Odds ratios; HR = Hazard ratios; CI = Confidence intervals; PAH = Polycyclic aromatic hydrocarbons
† adjusted for age and union status

4.1 Carcinogenic Exposures in Poultry Slaughtering and Processing Plants

There are six potentially carcinogenic exposures that occur in poultry plants: 1) poultry oncogenic viruses, such as ALSV, REV, MDV, and papilloma viruses [4,5,13], which may be found in live animals, raw poultry products, raw eggs, or in the air; 2) aflatoxin that is present in the air inside plants, that is produced by the fungus aspergillus [18]; 3) polycyclic aromatic hydrocarbons (PAHs) emitted during the smoking of poultry [19-21]; 4) benzene, phthalate, and PAHs present in fumes emitted from the wrapping machine during the wrapping of poultry [22,23]; 5) heterocyclic amines emitted during the cooking or frying of poultry meat [24,25]; and 6) exposure to nitrosamines during the curing of poultry meat [25-27].

Table 5. Adjusted odds ratios for non-poultry occupational exposures - all deaths from hematopoietic and lymphatic tumors combined (1990- 2003)

Non-poultry occupational exposures	Adjusted OR† (95% CI)
Exposure to coal, turpentine, naphthalene, natural gas, paraffin, etc.	5.6 (1.7 – 18.4)*
Sold seafood at work	4.3 (1.1 – 7.2)*
Worked in a stockyard	4.5 (0.3– 59.9)
Killed pigs	3.0 (1.0 – 9.1)#
Sprayed insecticides on a farm	3.0 (0.8 – 20.2)
Worked on a farm where animals other than poultry were raised for commercial purposes	2.2 (0.9 – 5.6)
Worked on a dairy farm	1.9 (0.6 – 5.7)
Worked in a gasoline station, gasoline storage facility	1.9 (0.5 – 7.0)

OR = Odds ratios; CI = Confidence intervals. † adjusted by age and union status
** Statistically significant at the 95% confidence level*
 # Borderline statistically significant at the 95% confidence level

Table 6. Odds ratios for non-poultry occupational exposures by histologic subtype of hematopoietic and lymphatic cancers, 1990-2003

Non-poultry exposures	Leukemia OR (95%CI) n=23	Lymphoma OR (95%CI) n=16	Multiple myeloma OR (95%CI) n=9
Sold seafood at work	2.1 (0.4-10.3)	3.6 (0.7-18.8)	6.3 (1.1-35.4)*
Exposure to coal, turpentine, naphthalene, natural gas, paraffin, etc.	3.4 (1.0-11.9)	6.1 (1.6-22.5)*	-----
Worked in a stockyard	3.2 (0.3-32.9)	5.7 (0.5-61.7)	-----
Killed pigs	1.1 (0.2-5.4)	5.1 (1.4-18.5)*	3.5 (0.7-18.6)
Sprayed insecticides on a farm	1.9 (0.4-9.3)	2.7 (0.5-13.9)	1.9 (0.2-16.7)
Worked on a farm where animals other than poultry were raised for commercial purposes	1.7 (0.5-5.4)	1.6 (0.4-6.2)	1.8 (0.4-9.4)
Worked on a dairy farm	1.1 (0.2-5.0)	1.7 (0.4-8.3)	3.3 (0.6-17.3)
Worked in a gasoline station, gasoline storage facility	1.2 (0.3-5.8)	2.0 (0.4-9.7)	-----

OR = Odds ratios; CI = 95% confidence intervals
** Statistically significant*

4.1.1 Carcinogenic exposure to poultry oncogenic viruses

Working as a poultry farmer, spreading of poultry wastes, handling raw eggs, working in the kill room, and contact with poultry blood involve tasks that would have brought workers in contact with high exposure to oncogenic viruses. These jobs were clearly associated with high risks of lymphoma or leukemia, except for killing and contact with blood, for which the increase was modest. One contributing factor to the lower risk estimates in this study was the relatively higher proportion of controls that were poultry workers (27%) compared to 1% in Metayer et al.'s study [8]. Controls in the current study were a random sample of the entire cohort, which also included poultry workers, while in the Metayer et al. [8]. study, the comparison group consisted of workers exclusively employed outside the meat industry. Our findings are consistent with those of the case-control study in which the reported risk for H & L tumors was twice as high in workers exposed to high levels of poultry and red meat blood combined [28]. The results are also consistent with the reported association of poultry farm exposure and non-Hodgkin's lymphoma [29], and also between growing up in a poultry farm and hematologic cancers [30].

The association of leukemia with handling eggs in supermarkets is interesting, bearing in mind that one of our studies showed that 1 in every 12 eggs displayed for sale in supermarkets in the New Orleans metropolitan area in the United States carried ALSV [31].

All of the poultry workers would have been potentially exposed to aflatoxin that would be present in the air inside the plants [18], or to papilloma viruses, because of the high prevalence of warts among them [5,6]. The role of these two exposures in the occurrence of these tumors cannot be ruled out, although it will be difficult to isolate them as independent risk factors in an epidemiologic study like this.

4.1.2 Carcinogenic exposure during smoking of poultry meat

Smoking of poultry meat that involves exposure to PAHs appeared to be associated with both leukemia and lymphoma. Although the ORs were not significant, the findings are consistent with the established causal association between PAHs and leukemia and lymphoma in humans [32].

4.1.3 Carcinogenic exposures during cooking or curing of poultry meat

The odds ratios for cooking or curing poultry meat were not elevated, suggesting that these exposures may not be involved in the excess occurrence of H & L tumors in poultry workers.

4.1.4 Carcinogenic exposure during wrapping of poultry meat

Surprisingly, the previously postulated possible association of these tumors with wrapping meat in supermarkets [7,8,33] was not evident here. A plausible explanation for the absence of an association in this report may be because all the responses for cases (who were all deceased) for exposure to fumes from the wrapping machine were from proxies who may not have known much about this specific exposure, while information for controls was mainly provided by the live study subjects themselves. In fact, the question on exposure to fumes from the wrapping machine was the least reliably reported exposure in the questionnaire, and, in the small validation study, the agreement between study subject and next-of-kin on this question was only 40%. Another reason is that this exposure was high and prevalent before 1975, and, after that date, it was drastically reduced to insignificant levels. The data in this study, however, are too sparse to investigate this exposure by calendar year of exposure. Thus, this study is unable to evaluate the effects of exposure to fumes from the wrapping machine.

4.2 Exposures Outside the Poultry Industry

Working in a stockyard handling cattle, pigs, sheep, or other animals appears to be associated with risk of tumors of the H& L systems. This is a consistent finding for other cancers in previous reports involving these same cohorts [8,34-36]. Although this activity does not involve exposure to poultry, it does involve possible exposure to the oncogenic viruses of cattle, pigs, sheep and goats such as the bovine leukemia virus, Jaagsiekte sheep retrovirus, and papilloma viruses of these animals. It also is consistent with the observed increased risk of leukemia and lymphoma associated with occupational exposure to beef cattle and working in the meat industry [28,37-40].

Selling seafood, killing pigs, and exposure to coal tar, turpentine, naphthalene, natural gas, paraffin, and smoke were all significantly associated with H & L tumors. The association between H & L tumors and coal tar and carbon products is established [32], and that with killing pigs is consistent with other reports [40]. However, the finding for selling seafood, especially in relation to multiple myeloma, is novel and unexpected, and would need to be confirmed in other studies.

We considered other explanations for the findings in this study. Though possible, selection bias is not likely to be a serious limitation in this study. All the cases that occurred in the cohort were included for study, and the controls were a random sample of the baseline cohort. Also, interviewed cases and controls were similar to their underlying source populations on demographic variables. Furthermore, 79% of the next-of-kin of cases that were contacted granted an interview, and for controls the response rate was 71%. Bias in the recall of exposures could potentially occur since responders for all cases and deceased controls were next-of-kin proxies, while responders for live controls were themselves the study subjects. As shown above, in the limited assessment of this issue, the agreement between the responses from proxies and those from the study subject themselves was quite good for the vast majority of responses. We lacked sufficient information regarding the duration of time involved in a specific occupational task. Hence, we were unable to determine whether there was a dose-response pattern. Also, the occupational task exposures were not mutually exclusive. Some employees had multiple jobs and therefore

multiple exposures within this industry. In this case, effect estimates may have been incorrectly estimated because of overlapping exposures. The diagnosis of H & L cases was based on underlying cause of death as coded in the death certificates. Previous studies found the detection and confirmation rates for hematopoietic cancers as the underlying cause of death were very high, with over 96% for leukemias and over 80% for lymphomas [41]. Thus, misclassification of disease should be less of a concern in our study.

5. CONCLUSION

In summary, this is a report of a pilot study, and limitations associated with pilot studies can be expected to be operative, especially the lack of statistical power, and therefore the findings should be regarded as preliminary. The study suggests an association between jobs in poultry slaughtering & processing plants involving exposure to oncogenic viruses and mortality from leukemia and lymphoma. This finding may be important considering that the general population is widely exposed to these viruses from contact with live chickens or ingestion of their raw or undercooked products including eggs, or through vaccination with vaccines manufactured by growing vaccine virus in contaminated eggs [14,15,16,31,42]. It does not appear that the excess occurrence of these tumors in poultry plants is associated with cooking or curing of poultry meat. The study could not adequately investigate carcinogenic exposures that occur during the smoking or wrapping of poultry meat, and these two exposures need to be investigated in studies with adequate statistical power.

The observed association with selling seafood, killing of pigs and working in a stockyard with these tumors are preliminary, and in the case of selling seafood new, and could be chance findings. The study though small was able to replicate the established association between exposure to byproducts of coal tar and natural gas that may contain PAH and benzene that cause leukemia and lymphoma. Also, leukemia and lymphoma have been linked with exposure to gasoline in gasoline stations and gasoline storage facilities and pesticides [32]. The finding that these established relationships were also replicated to a degree in this small study gives some credence to the new associations reported here. The uniqueness of the study lies in its singular focus on poultry workers, a group that carries the distinction of having one of the highest known human exposures to the oncogenic viruses of poultry. Ours is the only study of its kind to provide any detail on potential associations between occupational exposures in poultry plants and the occurrence of hematopoietic and lymphatic malignancies. The findings should be regarded as preliminary, but importantly, they point to possible risk factors (both poultry and non-poultry related) for these tumors that may need further investigation and replication in other studies with sufficient statistical power, especially as they also have implications for the general population. Finally, this pilot study indicates full blown larger studies are feasible, and point to issues that may need to be addressed in these studies. These findings call for a possible role of agencies such as the International Agency for Research on Cancer (IARC) and the National Institute for Occupational Safety & Health (NIOSH) to promote such studies, and for an agency such as the US Occupational Safety & Health Administration (OSHA) to begin to consider biological monitoring of exposures in the workplace for this occupational group.

CONSENT

Access to study subjects' union records was granted by the United Food & Commercial Workers International Union in Washington DC. Live study subjects and next-of-kin were read an informed consent document over the phone prior to interview, and granting of the interview was considered consent given. This measure was approved by the IRB.

ETHICAL APPROVAL

Approval was provided by the Human Subjects Committee (Institutional Review Board) of the University of North Texas Health Science Center – Approval Number IRB # 25-32.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Small-scale poultry processing; 1992. Available:http://www.fao.org/docrep/003/t0561e/t0561e00.htm
2. Encyclopedia of occupational health and safety. International Labor Office (Geneva). McGraw-Hill. 1972;2-228.
3. Kotula AW, Kinner JA. Airborne microorganisms in broiler processing plants. Appl Microbiol. 1964;12(3):179-84.
4. Saif YM. Diseases of poultry. Ames IA. Iowa State Press; 2003.
5. Gissmann L. Papillomaviruses and their association with cancer in animals and in man. Cancer Surv. 1984;3:161-81.
6. Mergler D, Vezina N, Beauvais A. Warts among workers in poultry slaughter houses. Scand J Work Environ Hlth. 1982;8(Suppl 1):180-4.
7. Johnson ES, Shorter C, Rider B, Jiles R. Mortality from cancer and other diseases in poultry slaughtering/processing plants. Int J of Epidemiol. 1997;26(6):1142–50.
8. Metayer C, Johnson ES, Rice JC. Nested case-control study of tumors of the hemopoietic and lymphatic systems among workers in the meat industry. Am J Epidemiol. 1998;147(8):727-38.
9. Moore T, Brennan P, Becker N, de Sanjosé S, Maynadié M, Foretova L, et al. Occupational exposure to meat and risk of lymphoma: A multicenter case-control study from Europe. Int J Cancer. 2007; 121(12):2761–6.
10. Johnson ES, Zhou Y, Yau CL, Prabhakar D, Ndetan H, Singh K, et al. Mortality from malignant diseases - update of the Baltimore union poultry cohort. Cancer Causes Control. 2010;21:215-21.
11. Johnson ES, Ndetan H, Lo KM. Cancer mortality in poultry slaughtering/processing plant workers belonging to a union pension fund. Environ Res. 2010;110(6):588-94.
12. Johnson ES, Zhou Y, Yau CL, Sarda V, Preacely N, Bankuru S, et al. Update of cancer and non-cancer mortality in the Missouri poultry cohort. Am J Ind Med. 2011;54(1):49-54.
13. Johnson ES. Poultry oncogenic retroviruses and humans. Cancer Detect Prev. 1994;18(1):9-30.
14. Johnson ES, Nicholson LG, Durack DT. Detection of antibodies to avian leukosis/sarcoma viruses (ALSV) and reticuloendotheliosis viruses (REV) in humans by ELISA. Cancer Detect Prev. 1995;19:394-404.
15. Johnson ES, Overby L, Philpot R. Detection of antibodies to avian leukosis/sarcoma viruses and reticuloendotheliosis viruses in humans by Western blot assay. Cancer Detect Prev. 1995;19:472-86.
16. Choudat D, Dambrine G, Delemotte B, Coudert F. Occupational exposure to poultry and prevalence of antibodies against Marek's disease virus and avian leukosis retroviruses. Occup Environ Med. 1996;53:403-10.
17. Tsang SX, Switzer WM, Shanmugam V, Johnson JA, Goldsmith C, Wright A, et al. Evidence of avian leukosis virus subgroup E and endogenous avian virus in measles and mumps vaccines derived from chicken cells. Investigation of transmission to vaccine recipients. J Virol. 1999;73(7):5843-51.
18. Viegas C, Malta-Vacas J, Sabino R, Viegas S, Veríssimo C. Accessing indoor fungal contamination using conventional and molecular methods in Portuguese poultries. Environ Monit Assess. 2014;186: 1951–9.
19. Nordholm L, Espensen I, Jensen HS, Holst E. Polycyclic aromatic hydrocarbons in smokehouses. Scand J Work Environ Hlth. 1986;12:614-8.
20. Colmsjö AL, Zebühr YU, Ostman CE. Polycyclic aromatic compounds in curing smoke. Z Lebensm Unters Forsch. 1984; 179(4):308-10.
21. Hansen AM, Olsen IL, Poulsen OM. Polycyclic aromatic hydrocarbons in air samples of meat smokehouses. Sci Tot Environ. 1992;126(1-2):17–26.
22. Vandervort R, Brooks SM. Polyvinyl chloride film thermal decomposition products as an occupational illness: I. Environmental exposures and toxicology. J Occup Med. 1977;19:188-91.
23. Smith TJ, Cafarella JJ, Chelton C, Crowley S. Evaluation of emissions from simulated commercial meat wrapping operations using PVC wrap. Am Ind Hyg Assoc J. 1983;44:176-83.
24. Vainiotalo S, Matveinen K. Cooking fumes as a hygienic problem in the food and catering industries. Am Ind Hyg Assoc J. 1993;54(7):376-82.

25. Jakszyn P, Agudo A, Ibáñez R, García-Closas R, Pera G, Amiano P, et al. Development of a food database of nitrosamines, heterocyclic amines, and polycyclic aromatic hydrocarbons. J Nutr 2004;134:2011-4.
26. Sen NP, Miles WF, Donaldson B, Panalaks T, Iyengar JR. Letter: Formation of nitrosamines in meat curing mixture. Nature. 1973;245:104-5.
27. Sen NP, Donaldson B, Charbonneau C, Miles WF. Effect of additives on the formation of nitrosamines in meat curing mixtures containing spices and nitrite. J Agric Food Chem. 1974;22(6):1125-30.
28. Fritschi L, Johnson KC, Kliewer EV, Fry R. Canadian cancer registries epidemiology research group. Animal-related occupations and the risk of leukemia, myeloma, and non-Hodgkin's lymphoma in Canada. Cancer Causes Control. 2002;13:563-71.
29. Beane Freeman LE, De Roos AJ, Koutros S, Blair A, Ward MH, Alavanja M, Hoppin JA. Poultry and livestock exposure and cancer risk among farmers in the Agricultural Health Study. Cancer Causes Control. 2012;23:663-70.
30. t Mannetje A, Eng A, Pearce N. Farming, growing up on a farm, and haematological cancer mortality. Occup Environ Med. 2012;69:126-32.
31. Pham TD, Spencer JL, Johnson ES. Detection of avian leucosis virus in albumen of chicken eggs using reverse transcription polymerase chain reaction. J Virol Meth. 1999;78(1-2):1-11.
32. IARC. International Agency for Research on Cancer. Monographs on the evaluation of carcinogenic risk of chemicals to humans. Polynuclear aromatic compounds, Part 4, bitumens, coal-tars, and derived products. Shale-oils and soots. Lyon, France. 1985; 35.
33. Johnson ES. Cancer mortality among workers in the meat department of supermarkets. Occup Environ Med. 1994; 51:541-7.
34. Johnson ES. Nested case-control study of lung cancer in the meat industry. J Natl Cancer Inst. 1991;83(18):1337-9.
35. Felini M, Johnson E, Preacely N, Sarda V, Bangara S, Ndetan H. A pilot case-cohort study of liver and pancreatic cancers in poultry workers. Ann Epidemiol. 2011; 21(10):755-66.
36. Felini MJ, Preacely N, Shah N, Christopher A, Sarda V, Elfaramawi M, et al. A case-cohort study of lung cancer in poultry and control workers: Occupational findings. Occup Environ Med. 2012;69(3):191-7.
37. Bethwaite P, McLean D, Kennedy J, Pearce N. Adult-onset leukemia and employment in the meat industry: A New Zealand case-control study. Cancer Causes & Control. 2001;12:635-42.
38. Pearce N, Smith AH, Reif JS. Increased risks of soft tissue sarcoma, malignant lymphoma, and acute myeloid leukemia in abattoir workers. Am J Ind Med. 1988;14: 63-72.
39. Reif JS, Pearce NE, Fraser J. Cancer risks among New Zealand meat workers. Scand J Work Environ Hlth. 1989;15(1):24-9.
40. Johnson ES, Ndetan H, Felini MJ, Faramawi MF, Singh KP, Choi KM, et al. Mortality in workers employed in pig abattoirs and processing plants. Environ Res. 2011;111(6):871-6.
41. Percy C, Stanek E, Gloeckler L. Accuracy of cancer death certificates and its effect on cancer mortality statistics. Am J Pub Hlth. 1981;71(3):242-50.
42. Hussain AI, Johnson JA, Da Silva Freire M, Heneine W. Identification and characterization of avian retroviruses in chicken embryo-derived yellow fever vaccines: Investigation of transmission to vaccine recipients. J Virol. 2003;77: 1105-11.

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