OPEN ACCESS

Original research

Cancer and all-cause mortality among United States union poultry workers

M Alexander Ball ,[1] Benjamin C Amick III,[1,2] Wendy N Nembhard ,[1] Christina C Joshua,[1] Leanna M Delhey,[1] Samuel L Schach,[3] Jaimi L Allen [1,2]

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/oemed-2025-110495).

[1]Department of Epidemiology, Fay W. Boozman College of Public Health, University of Arkansas for Medical Sciences, Little Rock, Arkansas, USA
[2]Winthrop P Rockefeller Cancer Institute, University of Arkansas for Medical Sciences, Little Rock, Arkansas, USA
[3]College of Medicine, University of Arkansas for Medical Sciences, Little Rock, Arkansas, USA

Correspondence to
Dr Jaimi L Allen;
jlallen@uams.edu

Received 8 August 2025
Accepted 18 February 2026

ABSTRACT

Objectives Several industry-specific hazards are present in the poultry working environment. It is not well known whether risk factors unique to poultry working increase all-cause and cancer mortality relative to other industry types. The study objective was to compare all-cause and cancer mortality among poultry workers to non-poultry food workers.

Methods Occupational data for 30 411 poultry and 16 405 non-poultry workers were obtained from United Food and Commercial Workers union records and matched to the National Death Index up to 31 December 2019 to conduct a retrospective cohort study. Unadjusted and adjusted hazard ratios (aHR) and their 95% CIs from time-stratified Cox proportional hazard regression models were run to compare all-cause and cancer mortality among poultry and non-poultry workers.

Results Across the full cohort, no statistically significant elevation in all-cause or cancer mortality among poultry workers was observed (all-cause: aHR 0.98, 95% CI 0.95 to 1.01; cancer: aHR 1.05, 95% CI 0.97 to 1.13); however, time-period sensitivity was evident. After accounting for calendar time, poultry workers hired before 1960 had a 62% greater cancer mortality hazard compared with non-poultry workers (aHR 1.62, 95% CI 1.25 to 2.11). Poultry workers hired between 1980 and 1989 had a 59% (aHR 1.59, 95% CI 1.40 to 1.79) and 86% (aHR 1.86, 95% CI 1.39 to 2.48) greater all-cause and cancer mortality risk, respectively.

Conclusions Union poultry workers hired in the United States during the 20th century faced greater all-cause and cancer mortality compared with non-poultry workers; however, this elevation was period-sensitive, varying by employment start date.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Several work environment exposures found in poultry processing have been associated with poor health outcomes, namely respiratory diseases, injuries and cancers.

WHAT THIS STUDY ADDS

⇒ This study is the longest mortality study of union poultry workers in the United States. Our analytic approach of the full UFCW cohort was also the first to consider time period sensitivity.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our results indicate elevated mortality among poultry workers for certain hiring cohorts. Future research should use an ecological lens, providing foundational information to influence public health efforts on industrial standards and safety regulations.

INTRODUCTION

Poultry consumption in the United States (US) has tripled since the mid-1950s, driving workforce demand and labour output expectations.[1–3] Individuals employed in the poultry production supply chain are often from low-income, immigrant or rural populations.[4–6] Historically, these populations have an elevated risk for poor health outcomes and are disproportionately impacted by hazardous work environments.[4] Poultry jobs add an additional layer of risk as they are one of the most dangerous and physically demanding manufacturing jobs in the US.[7] Employees are often expected to work for longer than 8 hours in confined spaces that often include hazardous chemicals, air-borne particulate matter and infectious biological agents.[7–9] Excess acute and chronic diseases have been associated with poultry working, with suspected exposures from raising, handling, slaughtering and processing live or raw poultry products.[10 11] Working in these environments has also been associated with oropharyngeal, lung and oesophageal cancer.[11 12]

While several studies have investigated poultry working, there is little consensus on the evidence of poultry working and adverse health or cancer outcomes resulting in excess mortality. For instance, asthma, rhinitis and chronic bronchitis have been associated with organic and inorganic poultry dust often found in poultry settings.[13] Microbial agents from poultry shedding and manure, and the disinfectants and detergents used in the poultry cleaning process are also linked to respiratory diseases.[13 14] Poultry oncogenic viruses, such as Marek's disease virus, avian leukosis/sarcoma virus and reticuloendotheliosis, formaldehyde in poultry cleaning agents and several other carcinogens have been suspected to cause cancer in humans; however, the research is sparse and the findings are inconclusive.[15–20]

There is limited evidence to strongly link poultry working and cancer mortality due to weak exposure measurement and study follow-up.[21] Our study objective was to compare all-cause and cancer mortality among United Food and Commercial Workers (UFCW) union poultry to non-poultry workers from 1 January 1950 to 31 December

Check for updates

To cite: Ball MA, Amick III BC, Nembhard WN, *et al*. *Occup Environ Med* Epub ahead of print: [please include Day Month Year]. doi:10.1136/oemed-2025-110495

2019. This analysis took advantage of a long follow-up period to evaluate period-specific effects, reflecting changes in poultry working risk during a 40-year study period. Our a priori hypothesis was that poultry workers would have a greater all-cause and cancer mortality compared with non-poultry workers.

METHODS

This is a retrospective cohort study of US poultry and non-poultry workers employed at industrial plants enrolled in the UFCW union. Workers were members of the UFCW Meatcutters' Union in Baltimore, Maryland, the UFCW Poultry Union in Marshall, Missouri, or the UFCW Union Pension Fund in Chicago, Illinois between 1950 and the end of 1989.

The UFCW cohort

Union records were obtained to extract industry type, hire and termination dates, employment site location and age on 30411 workers from 23 poultry slaughtering and processing plants in six states (Arkansas, Louisiana, Maine, Maryland, Missouri and Texas). There were 16405 non-poultry workers identified from 10 states (Florida, Illinois, Indiana, Maryland, Massachusetts, New Jersey, Ohio, Pennsylvania, Texas and Virginia) who worked in beverage, non-poultry food and manufactured metal container factories (eg, seafood, soft drinks, cheese and Asian food).

UFCW union workers were eligible for inclusion if they were employed between 1 January 1950 and 31 December 1989. Workers whose employment began before 1 January 1950 were eligible for inclusion in the study provided they were still employed past 1 January 1950. The employee start-times listed in UFCW union records had two interpretations. First, a worker began employment at a location with existing enrolment in the UFCW union and was obligated to become a UFCW union member within 30 days of employment. Second, a worksite location joined the UFCW union and the date the site enrolled in the union was listed as the start date for the employees who were already working there.

Cohort members deceased before or on 31 December 2010 were identified in previous analyses using the National Death Index (NDI) and databases listed elsewhere.[22 23] Members with living and unknown vital status on 31 December 2010 were linked to the National Death Index up to 31 December 2019. Cause of death was coded according to the ninth Revision of the International Classification of Diseases (ICD). Individuals whose vital status was unknown to the NDI as of 31 December 2019 were considered to be alive at study end.[24]

To account for analytic time period sensitivity, changing safety regulations and occupational differences between cohort members employed between 1 January 1950 and 31 December 1989, workers were separated by hire date into four employment periods: before 1 January 1960, between 1 January 1960 and 31 December 1969, between 1 January 1970 and 31 December 1979, and between 1 January 1980 and 31 December 1989. Industry type classified workers as in the poultry processing industry or other non-poultry food industries. Ascertainment of dichotomous race and biological sex information for the cohort has been explained in detail by Johnson *et al*, but what was previously labelled non-White has been renamed to Black, Indigenous and people of colour (BIPOC).[25] Worksite location was categorised from state-level data into the four US Census Bureau categorizations (the Northeast, the Midwest, the South and the West).[26]

Data analysis

Person-time was calculated using employment start dates and the end of follow-up on 31 December 2019 or the date of death identified for deceased cohort members. χ^2 tests of independence were computed for all outcomes and covariate levels by industry type. Two-sample t-tests were calculated to test differences in mean follow-up time, employment duration, time to all-cause mortality and time to cancer mortality by industry type. Cox proportional hazard (PH) regression modelling was run to estimate unadjusted and adjusted HRsHRs and their 95% CIs of poultry compared with non-poultry workers for all-cause and cancer mortality, adjusting for employment start date, race, sex, age at hire date, worksite location by US region, and employment duration. Time-period sensitivity and the Cox proportional hazards assumption were formally tested using an interaction term between industry type and the follow-up time variable, and the Supremum Test for Cox Proportional Hazards Assumption. Time stratification is a straightforward method to address time-period sensitivity and proportional hazards violations, and as such, four time-stratified Cox PH regression models were run for all-cause and cancer mortality to address the time-period sensitivity uncaptured by the cohort-wide HR.[27] Subsequently, several sensitivity analyses were run, including using alternative period definitions, subgroup analyses by various restrictions of employment duration and non-poultry industry type, and measures of potential residual confounding using E-values. To elucidate changes in the main effect, each covariate was added independently to the models as a categorical or continuous variable before the final models were constructed; $p<0.05$ was considered statistically significant. All analyses were completed using SAS software v9.4.[28]

RESULTS

Of 46816 identified union workers, those with missing employment, age, sex, race, or worksite location information (n=997) were excluded from the final analysis (figure 1). At the end of the study period, 10712 poultry workers (35%) and 7554 non-poultry workers (46%) were deceased (table 1). The mean follow-up time from the date of hire to death or the end of the study period was 37.60 years for the whole cohort, 37.30 years for poultry workers, and 39.04 years for non-poultry workers (table 2). Mean time to all-cause and cancer mortality was statistically significantly shorter among poultry workers compared

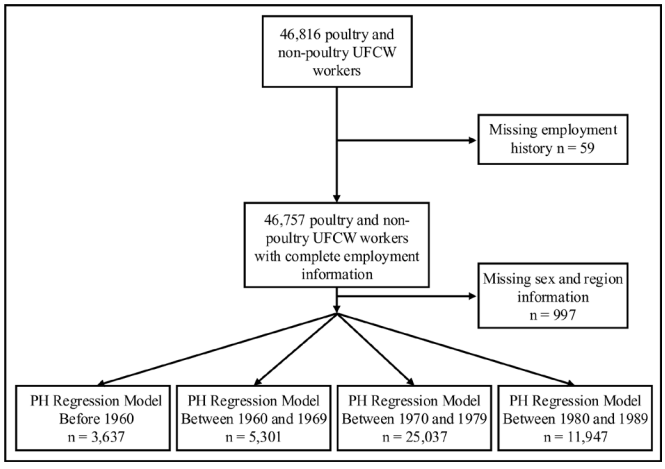

Figure 1 Flowchart diagram of missingness and final analytic sample sizes. PH, Cox proportional hazard; UFCW, United Food and Commercial Workers

Table 1 Study population characteristics for categorical variables (n=46 816)

	Poultry	Non-poultry
	n (%)*	n (%)*
Industry type	30 411 (65%)	16 405 (35%)
Cancer death	1832 (6%)	1185 (7%)
All-cause death	10 712 (35%)	7554 (46%)
Sex		
Male	12 763 (42%)	9493 (58%)
Female	16 986 (56%)	6763 (41%)
Race		
White	21 874 (72%)	12 616 (77%)
BIPOC†	8537 (28%)	3789 (23%)
State		
Arkansas	13 746 (45%)	0
Florida	0	230 (1%)
Illinois	0	302 (2%)
Indiana	0	130 (1%)
Louisiana	1163 (4%)	0
Maine	3757 (12%)	0
Maryland	2408 (8%)	5858 (36%)
Massachusetts	0	2803 (17%)
Missouri	8223 (27%)	0
New Jersey	0	299 (2%)
Ohio	0	2666 (16%)
Pennsylvania	0	3362 (20%)
Texas	943 (3%)	564 (3%)
Virginia	0	175 (1%)
Unknown	187 (1%)	0
Worksite Region‡		
The US Northeast	8223 (27%)	3098 (19%)
The US Midwest	3757 (12%)	6464 (39%)
The US South	18 260 (60%)	6827 (42%)
Employment start times		
Prior to 1960	613 (2%)	3048 (19%)
1960 – 1969	3157 (10%)	2191 (13%)
1970 – 1979	16 689 (55%)	8619 (53%)
1980 – 1989	9951 (33%)	2489 (15%)
Age at hire date		
≤24	14 083 (46%)	6649 (41%)
25–34	8509 (28%)	4825 (29%)
35–44	3900 (13%)	2436 (15%)
45–54	2818 (9%)	1531 (9%)
55+	1101 (4%)	906 (6%)

*Percentages totaling <100% are due to missingness (662 poultry and 149 non-poultry workers with missing sex; 16 non-poultry workers with missing state of employment; 1 poultry and 58 non-poultry workers with missing follow-up start times; 58 non-poultry workers with missing age at recruitment).
†Black, Indigenous and people of colour.
‡Region groups were categorised based on the US Census Bureau definitions of US regionality. χ^2 Test of Homogeneity was run for each stratum, and all reported results in the table were significant at p<0.0001.
BIPOC, Black, Indigenous and people of color.

with non-poultry workers (poultry workers: all-cause: 29.22 years, cancer: 29.03 years; non-poultry: all-cause: 31.75 years, cancer: 31.34 years, p<0.0001). Mean employment duration was significantly shorter among poultry workers (2.72 years) than non-poultry workers (3.74 years) (p<0.0001).

The unadjusted and adjusted cohort-wide Cox PH regression models for all-cause and cancer mortality indicated violations of the proportional hazards assumption, with significant interaction terms between the primary industry type variable and the time variable (all-cause: p<0.0001; cancer: p<0.0001). The Supremum Test for all-cause mortality was statistically significant (p<0.0001); however, not for cancer mortality (p=0.3820). Considering the contextual changes in cancer mortality trends in the US, graphical examination of the log-minus-log plot, and the significant time interaction term for cancer mortality, we concluded time stratification was necessary to address statistical and contextual time sensitivity. As such, Cox PH regression models were stratified evenly into four hiring periods, an appropriate method for dealing with proportional hazard violations for Cox PH models[27] (figure 1).

All-cause mortality

Across the full cohort period, there was no observed elevation in all-cause mortality hazard (aHR 0.98, 95% CI 0.95 to 1.01). However, after stratifying to account for time period sensitivity and adjusting for covariates, poultry workers hired before 1960 had a 22% greater hazard of all-cause mortality compared with non-poultry workers (aHR 1.22, 95% CI: 1.10 to 1.35, p=0.0002; table 3). No elevated risk for all-cause mortality was observed for poultry workers hired between 1960 and 1979 (1960–1969: 0.96 95% CI 0.88 to 1.04, p=0.3234; 1970–1979: aHR 0.97, 95% CI 0.93 to 1.02, p=0.2668). A 59% greater hazard of all-cause mortality was observed among poultry workers recruited between 1980 and 1989 (aHR 1.59, 95% CI1.40 to 1.79, p<0.0001). Male union workers had an elevated all-cause mortality hazard compared with female union workers in each period (aHRs 1.37–1.52; online supplemental Table 1). Union workers aged 25 years or older at first hire had significantly higher risk of all-cause mortality throughout the study period compared with union workers hired at ages younger than 25 (aHRs 1.39–19.56). BIPOC workers did not significantly differ in all-cause mortality compared with White poultry workers, with the exception of a slight elevation among those hired between 1970 and 1979 (aHR: 1.08, 95% CI 1.02 to 1.14, p=0.0041). Employment duration was not associated with all-cause mortality in the final models. No non-poultry workers were employed in the Northeast and the Midwest between 1950 and 1959; hence, aHRs were incalculable. Workers in the Northeast and the Midwest had lower risk of all-cause mortality compared with those in the South in the 60s and 70s, but was non-significant in the 80s (Midwest aHRs: 0.67–0.96; Northeast aHRs 0.80–1.01).

Cancer mortality

Across the full cohort period, there was a slightly non-significant elevation in cancer mortality hazard (aHR 1.08, 95% CI 1.00 to 1.18, p=0.0601). After stratifying by hire date, poultry workers had a 62% greater cancer mortality hazard compared with non-poultry workers (aHR 1.62, 95% CI 1.25 to 2.11, p=0.0003; table 4). No difference in the hazard of cancer mortality was observed for poultry workers recruited between 1960 and 1979 (1960–1969: aHR 1.03, 95% CI 0.82 to 1.28, p=0.8298; 1970–1979: aHR 0.96, 95% CI 0.86 to 1.07, p=0.4734). Poultry workers hired between 1980 and 1989 had an 86% greater cancer mortality hazard compared with non-poultry workers (aHR 1.86, 95% CI 1.39 to 2.48, p<0.0001). Male union workers had greater hazards of cancer mortality than female union workers throughout the study period (aHRs 1.34–1.93; online supplemental Table 1). Poultry workers hired at ages 25 years or older at first hire had higher cancer mortality hazards

Table 2 Study population characteristics for continuous variables

Variable	Cohort-wide		Poultry		Non-poultry			
	Mean (years) (SD)	n	Mean (years) (SD)	n*	Mean (years) (SD)	n*	*t*-value	P value
Follow-up time†	37.60 (11.29)	46758	37.30 (10.21)	30411	39.04 (13.32)	16347	14.64	<0.0001
Employment Duration	3.09 (4.20)	46758	2.72 (3.83)	30411	3.74 (4.70)	16347	23.78	<0.0001
Time to all-cause mortality‡	30.24 (12.87)	18219	29.22 (11.92)	10712	31.75 (14.0)	7507	12.74	<0.0001
Time to cancer mortality	29.93 (12.06)	3017	29.03 (11.29)	1832	31.34 (13.05)	1185	4.99	<0.0001

*Observations with missing follow-up information were removed.
†Follow-up times include both deceased and living cohort members.
‡Time to all-cause mortality includes both cancer and non-cancer mortality.

than poultry workers who began working at a younger age (aHRs 1.56–22.61). Race and employment duration were not associated with elevated cancer mortality hazards for the duration of the study period. Workers in the Midwest had a lower risk of cancer mortality compared with those in the South in the 60s and 70s; whereas the Northeast had reduced cancer mortality only in the 70s (Midwest aHRs: 0.72–0.68, respectively; Northeast aHRs 1.04–0.84, respectively). Cancer mortality did not vary by region in the 80s (Northeast aHR: 1.22, 95% CI 0.91 to 1.63, p=0.1851; Midwest aHR: 1.11, 95% CI 0.87 to 1.40, p=0.4042).

Sensitivity analyses

We conducted multiple sensitivity analyses to evaluate the robustness of the observed associations. In the final analyses, we observed a period-specific risk pattern resembling a U-shape, such that poultry workers who began working in the 50s and 80s had greater risk of all-cause and cancer mortality compared with non-poultry workers. To determine whether this U-shape risk pattern was robust to varying definitions of hire cohort, we re-ran the analyses using 5 year intervals (online supplemental Table 2). In the 5-year stratification analyses, a U-shape risk pattern was used, such that the risk decreased from the 50s to the 60s and subsequently rose again in the 80s. The final stratifications were left in 10 year intervals to ensure adequate sample size and reduce unstable standard errors and CIs.

Next, non-poultry workers enrolled in the UFCW union comprise a heterogeneous population. We ran cohort-wide and time-stratified Cox PH regression models comparing poultry workers to sub-groups of non-poultry workers using the following categorizations: seafood (n=6615), non-poultry meat (n=1845), general foods (n=7174), and packing and other (n=771). Before accounting for time sensitivity, poultry workers had a statistically significantly greater hazard of cancer mortality compared with other non-poultry meat workers and decreased all-cause and cancer mortality compared with those in the packaging work (online supplemental Table 3). However, non-poultry sub-group specific comparisons were also affected by time period sensitivity, such that no consistent elevation or reduction in risk was observed across the time-stratified study period.

Finally, the cohort-wide adjusted all-cause and cancer mortality Cox PH regression models were re-run after restricting the sample size to increasing levels of employment duration (at least 1 year, 5 years, 10 years and 15 years employed). A marginal elevation in all-cause and cancer mortality was observed among poultry workers across all strata of employment duration (online supplemental Table 4).

DISCUSSION

Our study sought to explore all-cause and cancer mortality hazards among poultry workers compared with non-poultry workers in the UFCW union cohort. This was the first study of the entire UFCW cohort to use a period-sensitive approach. Using a period-sensitive approach accounted for the changing work and social context of the 40-year hiring period, which may

Table 3 All-cause mortality HRs of poultry workers compared with non-poultry workers, stratified by employment start time

	Unadjusted HR (95% CI)	P value	n†	Adjusted HR (95% CI)*	P value	n†
Cohort-wide	0.91 (0.88 to 0.93)	<0.0001	30411	0.98 (0.95 to 1.01)	0.1967	29578
			16347			16240
Hire date before 1960						
Poultry	1.17 (1.05 to 1.29)	0.0030	613	1.22 (1.10 to 1.35)	0.00002	589
Non-poultry	Ref		3048	Ref		3048
Hire date between 1960 and 1969						
Poultry	0.92 (0.86 to 0.98)	0.0117	3157	0.96 (0.88 to 1.04)	0.3234	3149
Non-poultry	Ref		2191	Ref		2129
Hire date between 1970 and 1979						
Poultry	0.93 (0.89 to 0.97)	0.0007	16689	0.97 (0.93 to 1.02)	0.2668	16304
Non-poultry	Ref		8619	Ref		8593
Hire date between 1980 and 1989						
Poultry	1.19 (1.07 to 1.32)	0.0013	9.951	1.59 (1.40 to 1.79)	<0.0001	9535
Non-poultry	Ref		2489	Ref		2412

*Models adjusted for race, sex, age at recruitment, worksite location and employment duration.
†Due to missingness, 24 observations with hire dates before 1960, 70 observations with hire dates between 1960 and 1969, 411 observations with hire dates between 1970 and 1979 and 493 observations with hire dates between 1980 and 1989 were excluded in the adjusted models.

Table 4 Cancer mortality HRs of poultry workers compared with non-poultry workers, stratified by employment start time

	Unadjusted HR (95% CI)	P value	n†	Adjusted HR (95% CI)*	P value	n†
Cohort-wide	0.95 (0.88 to 1.02)	0.1750	30 411	1.08 (1.00 to 1.18)	0.0601	29 578
			16 347			16 240
Hire date before 1960						
Poultry	1.52 (1.18 to 1.97)	0.0013	613	1.62 (1.25 to 2.11)	0.0003	589
Non-poultry	Ref		3048	Ref		3048
Hire date between 1960 and 1969						
Poultry	0.83 (0.69 to 0.99)	0.0391	3157	1.03 (0.82 to 1.28)	0.8298	3149
Non-poultry	Ref		2191	Ref		2129
Hire date between 1970 and 1979						
Poultry	0.91 (0.83 to 1.01)	0.0676	16 689	0.96 (0.86 to 1.07)	0.4734	16 304
Non-poultry	Ref		8619	Ref		8593
Hire date between 1980 and 1989						
Poultry	1.20 (0.94 to 1.53)	0.1461	9.951	1.86 (1.39 to 2.48)	<0.0001	9535
Non-poultry	Ref		2489	Ref		2412

*Models adjusted for race, sex, age at recruitment, worksite location and employment duration.
†Due to missingness, 24 observations with hire dates before 1960, 70 observations with hire dates between 1960 and 1969, 411 observations with hire dates between 1970 and 1979 and 493 observations with hire dates between 1980 and 1989 were excluded in the adjusted models.

include changes in occupational safety regulations, workforce demographics, poultry consumer demand and calendar time. We observed a greater hazard of all-cause and cancer mortality among poultry workers who began employment before 1960 and between 1980 and 1989, even after multiple analytic constraints. Counter to our a priori hypothesis, this elevated mortality hazard was relative to calendar time. Due to insufficient information around poultry processing standards and practices during this time, the mechanism of elevated mortality hazard is not readily understood.

A more granular measurement of poultry workplace exposures could improve the interpretation of the observed associations between poultry work and cancer. Due to some missing information on employment start date for an unknown number of workers, the dates in which certain facility locations joined the UFCW union were captured, rather than the true date a member began working. Thus, this variable could not completely capture employment duration for an unknown proportion of cohort members, likely skewing the potential mortality hazard from poultry working toward the null. Moreover, we did not have a complete capture of employment history for all union workers, only the dates and occupations listed in the union rosters. Therefore, it is possible that some workers were occupied in both poultry and non-poultry food industries at some time. This misclassification of the exposure may have biased our results away or toward the null.

There is sparse research around the health outcomes and occupational experiences of non-union poultry and non-poultry food workers.[29] Therefore, these results are likely not generalisable to non-union poultry workers who are more likely to be Hispanic and/or previously immigrated.[30] Also, misclassification of the outcome may be present; analyses could not capture cancer incidence. Thus, it is likely that some poultry workers who died from non-cancer outcomes were diagnosed with cancer during the study period, but cancer was not the primary cause noted in the death certificate. Additionally, for those who were deceased after 1979, it is possible those not linked to the NDI were deceased but not captured. Finally, our study only contained information on a limited number of potential confounders. It is likely that other confounders exist in the relationship between poultry working and all-cause and cancer mortality; however, information was not available to adjust for them. As a result, it is possible that residual confounding, particularly that from tobacco smoking and alcohol consumption, may account for the observed estimated effects of poultry working on all-cause and cancer mortality. We explored the E-values of these potential confounders in the supplementary material (online supplemental Table 5).[31]

This research took advantage of a unique opportunity to explore mortality among poultry workers over time. The UFCW union cohort study is the longest and largest cohort study of poultry and non-poultry workers in the US. By comparing poultry workers within the UFCW union to non-poultry workers in other food industry roles, we selected a reference group with closer exchangeability than the US general population, which had been done in previous UFCW cohort-wide studies.[23 32] This comparison likely reduced confounding from demographic factors, as manufacturing workers are more often of the same socioeconomic status and are likely exposed to similar environmental factors. Additionally, our study contained workers from over 40 years of employment history, capturing the longest employment period of poultry working of any US study of poultry workers. Finally, this study is the first of the UFCW cohort to employ survival analysis of all cohort members and the first to control for period-specific effects.

This study extended earlier work of the UFCW union cohort to 31 December 2019.[23] These findings suggest poultry working may be associated with elevated all-cause and cancer mortality. However, it is possible that changes in poultry processing standards, safety and compliance, and labour demands between 1950 and 1989 are related to differences in mortality by calendar time.[33] Notably, the Occupational Safety and Health Act of 1970 instituted occupational regulations for worksite health and safety, which could explain the observed differences prior to 1960.[34] However, this does not explain the robust elevated all-cause and cancer mortality hazards of poultry workers employed after January 1, 1980. Future research into the poultry working environment should carefully define workplace exposures, accounting for the workforce transition in the 1990s and the current diversity of poultry workers, to more fully capture the relationship between poultry working and cancer.

Acknowledgements We would like to acknowledge the significant contributions of the late Eric Johnson, PhD, Professor of Epidemiology, and his tireless effort in recruiting and managing the UFCW union cohort.

Contributors Conception and design of underlying study: MAB, BCA and JLA. Literature review: MAB. Data analysis and interpretation: MAB, BCA, LMD, CCJ, SLS and JLA. Drafting of the manuscript: MAB. Guarantor: BCA. Drafting of the manuscript (analytical methods): MAB, BCA, and JLA. Critical revision: MAB, BCA, WNN, CCJ, LMD, SLS and JLA.

Funding This study was funded by the National Institute for Occupational Safety and Health within the Centers for Disease Control and Prevention, grant R03OH12121.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study was reviewed and approved by the University of Arkansas for Medical Sciences Institutional Review Board (135616).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. De-identified data may be available upon reasonable request from the cohort principal investigator.

ORCID iDs
M Alexander Ball https://orcid.org/0009-0004-5764-3194
Wendy N Nembhard https://orcid.org/0000-0002-8318-4049
Jaimi L Allen https://orcid.org/0000-0002-3781-939X

REFERENCES

1 UN Food and Agriculture Organization (FAO) – processed by Our World in Data. Food supply (kg per capita per year). UN Food and Agriculture Organization (FAO).
2 Gerber P, Opio C, Steinfeld H. Poultry production and the environment - a review. in: poultry in the 21st century: avian influenza and beyond. Proceedings of the International Poultry Conference; 2008:379–405.
3 FAO. World agriculture: towards 2030/2050 interim report. Rome Global Perspective Studies Unit, Food and Agriculture Organization of the United Nations; 2006. Available: https://www.fao.org/fileadmin/templates/em2009/docs/FAO_2006_.pdf
4 Landsbergis PA, Grzywacz JG, LaMontagne AD. Work organization, job insecurity, and occupational health disparities. *Am J Ind Med* 2014;57:495–515.
5 Lipscomb HJ, Epling CA, Pompeii LA, *et al*. Musculoskeletal symptoms among poultry processing workers and a community comparison group: Black women in low-wage jobs in the rural South. *Am J Ind Med* 2007;50:327–38.
6 Mora DC, Arcury TA, Quandt SA. Good job, bad job: Occupational perceptions among Latino poultry workers. *Am J Ind Med* 2016;59:877–86.
7 Poultry breeding, farming and transport | NIOSH | CDC. CdcGov; 2021. Available: https://archive.cdc.gov/www_cdc_gov/niosh/topics/poultry/breed.html
8 Farm worker, poultry: international hazard datasheets on occupation. International Labour Organization; 2012. Available: https://www.ilo.org/publications/farm-worker-poultry-international-hazard-datasheets-occupation
9 Magri CA, Garcia RG, Binotto E, *et al*. Occupational risks and their implications for the health of poultry farmers. *Work* 2021;70:815–22.
10 Fritschi L, Fenwick S, Bulsara M. Mortality and cancer incidence in a cohort of meatworkers. *Occup Environ Med* 2003;60:E4.
11 Besson H, Banks R, Boffetta P. Cancer mortality among butchers: a 24-state death certificate study. *J Occup Environ Med* 2006;48:289–93.
12 Felini M, Preacely N, Shah N, *et al*. A case-cohort study of lung cancer in poultry and control workers: occupational findings. *Occup Environ Med* 2012;69:191–7.
13 Ngajilo D, Singh T, Ratshikhopha E, *et al*. Risk factors associated with allergic sensitization and asthma phenotypes among poultry farm workers. *Am J Ind Med* 2018;61:515–23.
14 Ngajilo DA. Respiratory health effects in poultry workers. *Current Allergy and Clinical Immunology* 2014;27. Available: https://www.researchgate.net/publication/262938503_Respiratory_health_effects_in_poultry_workers
15 Choudat D, Dambrine G, Delemotte B, *et al*. Occupational exposure to poultry and prevalence of antibodies against Marek's disease virus and avian leukosis retroviruses. *Occup Environ Med* 1996;53:403–10.
16 Jabłońska S, Obalek S, Gołebiowska A, *et al*. Archives of dermatological research. *Epidemiology of Butchers' Warts* 1988;280:S24–8. Available: https://pubmed.ncbi.nlm.nih.gov/2841908/
17 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. Available: https://pubmed.ncbi.nlm.nih.gov/7585725/
18 Choi KM, Johnson ES. Industrial hygiene assessment of reticuloendotheliosis viruses exposure in the poultry industry. *Int Arch Occup Environ Health* 2011;84:375–82.
19 Beane Freeman LE, DeRoos AJ, Koutros S, *et al*. Poultry and livestock exposure and cancer risk among farmers in the agricultural health study. *Cancer Causes Control* 2012;23:663–70.
20 Durusoy R, Boffetta PMannetjeA 't*et al*. Lung cancer risk and occupational exposure to meat and live animals. *Intl Journal of Cancer* 2006;118:2543–7.
21 Schat KA, Erb HN. Lack of evidence that avian oncogenic viruses are infectious for humans: a review. *Avian Dis* 2014;58:345–58.
22 Johnson ES, Faramawi M, Chedjieu IP, *et al*. Excess lung cancer occurrence in poultry plants. Occupational risk factors: Findings for oncogenic viruses exposure and other occupational exposures. *Environ Res* 2018;167:393–410.
23 Johnson ES, Ndetan H, Lo K-M. Cancer mortality in poultry slaughtering/processing plant workers belonging to a union pension fund. *Environ Res* 2010;110:588–94.
24 Ter-Minassian M, Basra SS, Watson ES, *et al*. Validation of US CDC National Death Index mortality data, focusing on differences in race and ethnicity. *BMJ Health Care Inform* 2023;30:e100737.
25 Johnson ES, Dalmas D, Noss J, *et al*. Cancer mortality among workers in abattoirs and meatpacking plants: an update. *Am J Ind Med* 1995;27:389–403.
26 U.S. Census Bureau. Census regions and divisions of the United States. 1984. Available: https://www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf
27 Zhang Z, Reinikainen J, Adeleke KA, *et al*. Time-varying covariates and coefficients in Cox regression models. *Ann Transl Med* 2018;6:121.
28 SAS. Editorial guidelines. WwwSasCom; 2024. Available: https://www.sas.com/en_us/legal/editorial-guidelines.html
29 Leigh JP, Chakalov B. Labor unions and health: A literature review of pathways and outcomes in the workplace. *Prev Med Rep* 2021;24:101502.
30 Kandel W. USDA ERS - meat-processing firms attract hispanic workers to rural America. WwwErsUsdaGov; 2006. Available: https://www.ers.usda.gov/amber-waves/2006/june/meat-processing-firms-attract-hispanic-workers-to-rural-america/
31 VanderWeele TJ, Ding P. Sensitivity Analysis in Observational Research: Introducing the E-Value. *Ann Intern Med* 2017;167:268–74.
32 Johnson ES, Shorter C, Rider B, *et al*. Mortality from cancer and other diseases in poultry slaughtering/processing plants. *Int J Epidemiol* 1997;26:1142–50.
33 Whittaker W. 43. CRS report for congress labor practices in the meat packing and poultry processing industry: an overview. 2005. Available: https://www.nationalaglawcenter.org/wp-content/uploads/assets/crs/RL33002.pdf
34 United states department of labor. OSH act of 1970. In: *Occupational Safety and Health Administration*. 2004. Available: https://www.osha.gov/lawsregs/oshact/completeoshact