HealthHazard® Evaluation Program

Evaluation of Ergonomic Risks, Musculoskeletal Disorders, and Peracetic Acid Exposure Among Employees at a Pork Processing Plant in Pennsylvania

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The Health Hazard Evaluation Program investigates possible health hazards in the workplace under the authority of the Occupational Safety and Health Act of 1970 [29 USC 669a(6)]. The Health Hazard Evaluation Program also provides, upon request, technical assistance to federal, state, and local agencies to investigate occupational health hazards and to prevent occupational disease or injury. Regulations guiding the Program can be found in Title 42, Code of Federal Regulations, Part 85; Requests for Health Hazard Evaluations [42 CFR Part 85].

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Table of Contents

Main Report

Supporting Technical Information

Introduction

Request

Management of a pork processing plant requested a health hazard evaluation of ergonomics (fitting the job to the worker) and musculoskeletal disorders (injuries and illnesses of muscles, tendons, and nerves) among employees on the harvesting side of the plant. They were also concerned about employees' exposure to peracetic acid, a chemical used at the plant as a disinfectant. Because the evaluation occurred during the coronavirus disease 2019 (COVID-19) pandemic, management also requested a review of the COVID-19 policies and procedures in place at the time of the request.

Workplace

The plant received live hogs and produced pork products. On the harvesting side of the plant, live hogs were received and moved through the barn until they were stunned and killed. The hogs were then suspended by their hind legs from an overhead conveyor or chain. The chain moved the hogs at a set speed through the rest of the process. Employees stationed along the line did specific tasks to eviscerate (remove internal organs) the animal and remove the head. After the head and internal organs were removed, the carcass was moved to a cooler at the end of the line. Further processing of the carcass into pork products was completed on the other side of the plant, which was outside the scope of this evaluation.

We visited the workplace twice during this evaluation. At the time of our second visit in August 2022, the company planned to run the line on the harvesting side at an average speed of 1,106 hogs per hour, resulting in an estimated average of 11,000 hogs processed per day. During the visit, 201 full-time employees worked in the harvesting section, which was organized into four main work areas (barn, wet harvest, clean harvest, and offal). Employees in the barn area received live hogs and moved them through stunning. Employees in the wet and clean harvest work areas hung the hogs on the line and removed the viscera from the carcass. Employees in the offal work area prepared the head for packaging; removed, separated, and cleaned viscera; and packaged the cleaned viscera. Two shifts of employees staffed the barn. The rest of the harvesting side operated during one shift of about 8 hours. However, the actual length of each workday varied depending on the total number of hogs being processed and delays in production (for example, equipment malfunction).

The plant also had employees doing further processing and sanitation (cleaning) jobs. These employees were not part of the scope of this evaluation. Further processing occurred at the same time as harvesting on the other side of the plant. These employees broke down the hogs coming out of the hog cooler into various parts for packaging and distributing. Sanitation occurred overnight throughout the plant to sanitize all work surfaces and machinery in preparation for the next shift.

The evaluation of peracetic acid exposure occurred at a spray cabinet after the hogs left the hog cooler and went on for further processing. There was one employee workstation with potential for direct exposure to spray from the cabinet. This was the only location in the plant where peracetic acid was applied.

To learn more about the workplace, go to Section A in the Supporting Technical Information

Our Approach

We conducted a virtual walkthrough in May 2021. We then performed the onsite evaluation during two visits in July 2021 and in August 2022. During our onsite visits, we did the following:

- Observed work processes and work practices.
- Recorded videos of harvest job tasks.
- Measured pull forces in the hog cooler.
- Collected air samples for peracetic acid, acetic acid, and hydrogen peroxide.
- Measured peracetic acid, temperature, and relative humidity with direct reading instruments.
- Evaluated the local exhaust ventilation of the peracetic acid spray cabinet.
- Discussed medical policies and procedures for employees. These included using the occupational health unit and athletic trainer certified unit, which were on-site at the plant, along with referrals to outside services.
- Conducted confidential interviews with employees.

After the first visit, we reviewed the plant's written COVID-19 Assessment and Control Plan and provided recommendations. Following both visits, we reviewed injury and illness records.

To learn more about our methods, go to Section B in the Supporting Technical Information

Our Key Findings

Most job tasks we evaluated had hand activity levels and force above the American Conference of Governmental Industrial Hygienists' (ACGIH®) guidelines

- ACGIH is a scientific organization that publishes guidelines for use by safety and health professionals to make decisions about safe levels of exposure in the workplace. ACGIH has set limits for hand activity levels (the rate at which a worker's hands move when doing their job).
- The ACGIH threshold limit value (TLV®) is the level above which a worker's hand movement is considered unacceptable. ACGIH also has an action limit for hand activity level. Exposure levels above the action limit are a warning sign that the exposure levels are getting too high. When exposures are over the action limit, safety and health professionals should start thinking about reducing the amount of exposure for a task.
- Sixteen percent of the job tasks we measured had hand activity levels and force at or above the ACGIH threshold limit value.
- Almost half of job tasks (45%) had hand activity levels and force above the ACGIH action limit, but below the threshold limit value.

Work-related upper body musculoskeletal disorders and symptoms were common among harvesting side employees

- During May 2018–December 2021, the rate of upper body musculoskeletal disorders this facility reported on Occupational Safety and Health Administration (OSHA) Logs increased. By the end of the period, the rate was higher than the overall rate of injuries and illnesses reported for the animal slaughtering and processing industry (except poultry) in the United States. Upper body musculoskeletal disorders affect the neck, back, shoulders, elbows, wrists, hands, and fingers.
- This finding may mean there are more injuries and illnesses at this facility than other similar facilities. It could also mean that the plant's well-developed medical program improved their ability to detect injuries and illnesses and is better at detecting injuries and illnesses than the industry standard. Either way, this high and increasing rate of injuries and illnesses shows the need for additional controls.
- Most upper body musculoskeletal injuries and illnesses reported to OSHA involved the hands or wrists. The most common problems reported were trigger finger or thumb (also called stenosing tenosynovitis) and carpal tunnel syndrome.
- We estimated that more than a third (39%) of harvesting side employees, or about 70 employees, had experienced work-related symptoms pointing to upper body musculoskeletal disorders in the 12 months before our visit.

Peracetic acid, acetic acid, and hydrogen peroxide were detected at sampling locations near the peracetic acid spray cabinet using several scientific methods

- While detectable levels were found, the results do not show the need for further personal exposure monitoring for peracetic acid, acetic acid, or hydrogen peroxide. If there are changes in the work process (amount being used, concentration being used, how it is being used, where it is being used, etc.) then additional sampling would be needed to characterize exposures.
- We identified opportunities to improve engineering and administrative controls, which may reduce employee exposure to peracetic acid, acetic acid, and hydrogen peroxide. Engineering controls are changes made to the physical workplace. Administrative controls are changes to work practices (such as changing ways that work is done).

To learn more about our results, go to Section B in the Supporting Technical Information

Our Recommendations

The Occupational Safety and Health Act requires employers to provide a safe workplace.

Potential Benefits of Improving Workplace Health and Safety:

- Improved employee health and well-being
- Better workplace morale
- Easier employee recruiting and retention
- Enhanced image and reputation
- Superior products, processes, and services
- May increase overall cost savings

The recommendations below are based on the findings of our evaluation. For each recommendation, we list a series of actions you can take to address the issue at your workplace. The actions at the beginning of each list are preferable to the ones listed later. The list order is based on a well-accepted approach called the "hierarchy of controls." The hierarchy of controls groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or practical, administrative measures and personal protective equipment might be needed. Read more about the hierarchy of controls at https://www.cdc.gov/niosh/topics/hierarchy/.

We encourage the company to use a health and safety committee to discuss our recommendations and develop an action plan. Both employee representatives and management representatives should be included on the committee. Helpful guidance can be found in *Recommended Practices for Safety and Health Programs* at https://www.osha.gov/shpguidelines/index.html.

Recommendation 1: Reduce risk for musculoskeletal disorders

Why? Musculoskeletal disorders are conditions that involve the nerves, tendons, muscles, and supporting parts of the body. They can cause chronic pain and make moving painful or harder to do.

The best way to keep workers from having musculoskeletal disorders is to design tasks, workstations, tools, and other equipment to match the physical and psychological characteristics and capabilities of employees.

We found that many employees were doing highly repetitive (repeating the same tasks over and over) and forceful work. Many job tasks exceeded the ACGIH acceptable workplace levels for hand activity. Doing work that exceeds these levels increases the risk of work-related musculoskeletal disorders and related symptoms. Symptoms of these disorders were common in harvesting side employees. Reducing repetition (repeated job tasks), force, and awkward (uncomfortable) postures needed for these jobs will reduce upper body strain for employees.

How? At your workplace, we recommend these specific actions:

Evaluate job tasks to find ways to reduce repetition, force, and awkward postures.

- Find ways to reduce the risk for musculoskeletal disorders. Evaluate job tasks above the ACGIH threshold limit value first. Continue to evaluate and modify job task hand level activities until all job tasks are below the ACGIH action limit for hand activity level.
- Find the job tasks that can be automated or assisted by engineering controls.

Apply well-established interventions based on ergonomic design principles.

- Use information from OSHA about Ergonomics including the OSHA Ergonomics Program Management Guidelines for Meatpacking Plants. Also refer to relevant sections of the OSHA Prevention of Musculoskeletal Injuries in Poultry Processing guidance document to inform interventions.
- Use proven interventions to reduce repetitions per employee. These include decreasing the speed at which work is performed, increasing the number of employees assigned to a task, limiting overtime work, and providing rest pauses (breaks).
- Make using automation and other engineering controls a priority, when possible.
- Talk to employees and supervisors about possible changes to improve work methods before and after any changes are made. The design of effective engineering and administrative controls is best done with input from employees and supervisors who will be affected by the changes.

Modify workstations to reduce the need for excessive reaching or repetitive movements.

- Where feasible, consider installing pallet lifts where product is being placed on pallets and installing rotating/carousel pallet lifts where heavy items (such as heads) are being put on pallets. Consider using spring-actuated pallet lifts that adjust pallet height based on the weight applied to the pallet. Spring-actuated pallet lifts can be used instead of lifts that require the employee to raise or lower the height by hand.
- Removing the top row of hooks on the liver hanging racks will prevent employees from reaching above shoulder height.
- Ensure all work areas and departments are adequately staffed for the assigned tasks.

Create a job rotation plan to regularly rotate (move) job tasks for employees doing highly repetitive work.

- Develop and implement a "job rotation plan." This means moving employees who do repetitive work with their hands and fingers to other jobs that use other parts of their bodies.
- When low-risk jobs are available, rotate (move) employees on a regular basis between job tasks with exposures that exceed the action limit for hand activity level to job tasks with exposures that are below the action limit.
- After using the plan, evaluate whether it is helping to reduce ergonomic hazards and musculoskeletal symptoms, injuries, and illnesses. A job rotation plan that is working well will reduce the risk of musculoskeletal disorders.

Increase the number of breaks employees have to reduce the length of time they spend doing continuous work.

Use height-adjustable stands wherever stands have been added to workstations.

- Train employees how to identify a proper working height and how to adjust the stands to that proper height before they begin a new task.
- Tell employees how to ask for an adjustment if they need help adjusting the height of their stands.

Provide regular reminders to employees that adjustments to counterbalances can be made quickly.

- Ensure that employees are aware that the counterbalances can be adjusted quickly and that adjustments should be made prior to using any tool connected to a counterbalance.
- This is especially important when employees are taking over a position for just a short time while another employee goes on break.
- Stress that all employees should adjust their workstation, wherever possible, before beginning a new task.

Designate an ergonomics team responsible for correcting ergonomic hazards in the workplace.

- Include proper personnel from all levels on the team, such as ergonomics professionals, healthcare providers, safety and health professionals, supervisors, managers, and employees.
- Set up a process and schedule for the team to review information and decide on interventions.
- More information about the team's function and makeup can be found in OSHA's Ergonomics Program Management Guidelines for Meatpacking Plants.

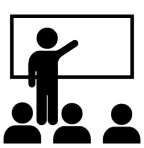
Recommendation 2: Improve monitoring of musculoskeletal symptoms, injuries, and illnesses to see if interventions need to begin or be changed

Why? Finding symptoms, injuries, and illnesses early can keep them from becoming severe. When symptoms are found, actions that can be taken include changing work practices or giving medical care. By monitoring where and when symptoms, injuries, and illnesses are happening, management can better understand where ergonomic risks are and take action to reduce them.

During the evaluation, we learned that training, including how to report symptoms or concerns, was provided to employees by management at orientation, by athletic trainers visiting the floor, and by medical staff from the occupational health unit. Trainings were provided in English and Spanish, yet employees spoke many other languages.

We reviewed data about injuries and illnesses from multiple sources. Company management reported monitoring these data regularly. While the company had a well-developed program, improvements can still be made to strengthen the program's ability to use these data to identify and evaluate interventions. For example, there were differences in the information available from each source. In addition, no formal standard operating procedure for analysis, review, reporting, or action was provided.

How? At your workplace, we recommend these specific actions:



Educate employees about signs and symptoms of musculoskeletal disorders.

- Train employees on the hazards associated with their jobs. This should include information on musculoskeletal disorders and the risk factors that cause or contribute to them. Training should also include how to recognize, prevent, and report any muscle- and bone-related symptoms. OSHA advises in their Ergonomics Program Management Guidelines for Meatpacking Plants to provide at least annual training for employees.

- Include information about recognizing symptoms of musculoskeletal disorders that are specific to each employee's job task in trainings. For example, encourage employees who work in jobs that involve repeated gripping to recognize and report symptoms of stenosing tenosynovitis of the fingers or thumb (also called "trigger finger" or "trigger thumb"). Symptoms include pain, stiffness, and a feeling of locking or catching when bending or straightening the fingers or thumbs.

Ensure that policies and procedures about reporting injuries and illnesses and taking leave for medical reasons are not punitive (do not punish the employee).

- Examine policies for reporting symptoms, injuries, or illnesses. Identify barriers that might stop or discourage employees from reporting.
- Change policies and procedures to lessen issues that would keep employees from reporting symptoms, injuries, or illnesses.

Improve injury and illness record keeping.

- Ensure that reportable injuries and illnesses are summarized by calendar year, which is consistent with OSHA's Injury and Illness Recordkeeping Rule (29 CFR 1904.32 Subpart D).
- Make certain the OSHA Logs and the records from the occupational health unit and athletic trainer certified unit are as complete as possible.
- If one does not already exist, begin consistently using a standard data collection tool for the occupational health unit and athletic trainer certified unit to track injuries and illnesses by nature, body part(s) affected, work characteristics (for example, work area, department, job title, job task, tenure), and disposition. Ensure that the tools work with each other to allow an injury or illness to be tracked through reporting, treatment, referrals, and resolution. Data collection tools can be as simple as a spreadsheet or rely on more sophisticated systems such as an electronic medical record system.

Continue to regularly analyze injury and illness data to direct changes to interventions.

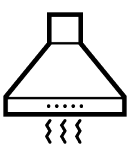
- Use injuries and illnesses recorded on OSHA Logs, or reported to the occupational health unit, athletic trainer certified unit, or any other incident reporting systems, to identify trends in the rate of injury or illness. Do this over time, in general, and by work area, department, job title, and job task. See Section C of OSHA's Ergonomics Program Management Guidelines for Meatpacking Plants for additional guidance on identifying, recording, and analyzing medical information.

- Establish a regular schedule to review injury and illness trends with the ergonomics team to identify tasks that need to be evaluated further. Ensure that the review protocols maintain privacy and confidentiality of private medical information.
- Begin using a system to formally track athletic trainer visits to the production floor, if not already in place. This will help identify trends in complaints, concerns, symptoms, injuries, and illnesses, if any.
- Consider collecting information including work area, department, job title, and job tasks as part of the pain medication dispensing process to allow for future injury and illness analysis.
- Use injury and illness data to evaluate how well interventions work.

Recommendation 3: Take steps to reduce exposure to peracetic acid

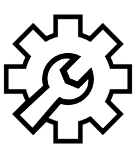
Why? Peracetic acid is a chemical used in a mixture with acetic acid and hydrogen peroxide in this plant. Peracetic acid can hurt the skin, mucous membranes (like your eyes and nose), and respiratory tract (mouth, nose, throat, airways, and lungs). Little information has been published on how to manage risk when working with mixtures of peracetic acid, acetic acid, and hydrogen peroxide.

How? At your workplace, we recommend these specific actions:



Consider operating the peracetic acid spray cabinet ventilation system at a greater airflow to improve capture of peracetic acid mist and vapor.

- Running the ventilation system at higher airflow will help it capture peracetic acid vapors and mist before they escape the spray cabinet. This will reduce possible exposures to employees. Any changes to ventilation airflow should be reviewed and verified by a ventilation expert to ensure that they have the intended effect.



Ensure that the peracetic acid spray cabinet is properly maintained.

- Properly maintain the ventilation and spray systems within the cabinet to ensure they are operating correctly. Add the spray cabinet ventilation to the maintenance plan. This means checking regularly to see if the cabinet is working as it should and that air is flowing properly (in the way it is designed to).
- Ensure that the ventilation and spray systems are operating within desired parameters with any changes to the production process (such as increasing peracetic acid target concentrations). Changes to the production process can change employees' potential peracetic acid exposures if adjustments are not made to the spray and ventilation systems.

Consider enclosing the spray cabinet to reduce the amount of peracetic acid leaving the entrance or exit of the cabinet.

- Spray cabinets can be better enclosed so that significant amounts of mists or droplets are not released through the entrance or exit to the cabinet.
- Clear plastic or stainless-steel shields at the entrance or exit of the cabinet can be used to deflect spray from contacting employees. Consider design features that facilitate easy removal for cleaning and maintenance.

Revisit whether further sampling is needed when there are any changes to how peracetic acid is used in the plant. For example, if there is an increase in the application concentration of peracetic acid, the number of application sites within the plant, or the production rate.

Recommendation 4: Address other health and safety issues we identified during our evaluation

Why? A workplace can have multiple health hazards that cause employee illness or injury. Similar to the ones identified above, these hazards can potentially cause serious health symptoms, lower morale and quality of life for your employees, and possibly increased costs to your business. We observed the following potential issues at your workplace:

- Compliance with hearing protection requirements could be improved. We observed some employees not wearing hearing protection while in production areas, despite these areas being designated as requiring hearing protection. We also observed many employees with earplugs that appeared to be inserted incorrectly (for example, nestled in the ear rather than rolled and inserted appropriately).
- We learned that translation of information into other languages and dialects was typically provided informally through supervisors or other team members who speak multiple languages.

Although they were not the focus of our evaluation, these hazards could cause harm to your employees' health and safety and should be addressed.

How? At your workplace, we recommend these specific actions:

Give employees refreshers about the importance of properly using and how to use hearing protection equipment, particularly ear plugs.

- Share information through several different ways (such as newsletters, video monitors, text messaging, and in-person supervisor reminders).

- Empower supervisors and employees to remind coworkers about hearing protection requirements.

Offer training and health and safety information in employees' preferred languages.

- With many languages and dialects spoken in the plant, employees may have difficulty understanding the training provided in English and Spanish.
- Providing health and safety information in preferred languages will help employees better understand workplace procedures and protocols.

Supporting Technical Information

Evaluation of Ergonomic Risks and Musculoskeletal Disorders, and Peracetic Acid Exposure Among Employees at a Pork Processing Plant in Pennsylvania

HHE Report No. 2021-0118-3411

May 2025

Section A: Workplace Information

Employee Information

Number of employees at time of the August 2022 site visit: 201

Length of shift: Median 10.5 hours/shift (range: 8–12.5 hours)

Union: No

Median age: 47 years old (range: 22–64 years old)

Median tenure at job: 4 years (range: <2 months to >30 years)

Process Description

The harvesting side of the plant included departments ranging from the barn to hog cooler, organized into four work areas (barn, wet harvest, clean harvest, and offal). During the week of our second visit, 201 full-time employees worked on the harvesting side including the barn (n = 23), wet harvest (n = 15), clean harvest (n = 81), and offal (n = 82) work areas. In the barn area, employees handled live hogs from when they were offloaded from trucks until they entered the serpentine department. In the serpentine department, employees moved the live hogs toward a stunning machine using rattle paddles and other handheld tools.

Employees in departments in the wet and clean harvest work areas worked to hang the hogs on the line and remove the viscera from the carcass. The offal work area was divided into three departments: offal head, offal pluck, and offal pack. Offal head prepared the head for packaging. Offal pluck removed, separated, and cleaned viscera. Offal pack packaged the cleaned viscera. A mechanical conveyor moved whole hog carcasses into the hog cooler, and then employees pushed the carcasses into the cooler bays to await further processing the next day. Employees pulled whole hog carcasses out of the cooler bays and onto the mechanical conveyor to remove them from the hog cooler. Employees generally did the same job within a department although some job rotation occurred. Peracetic acid (PAA) was applied using a spray cabinet just after hogs moved out of the hog cooler toward further processing. There was one employee workstation with potential for direct exposure to spray from the cabinet. The target concentration range of PAA in solution in the spray cabinet was 195–225 parts per million (ppm).

Section B: Methods, Results, and Discussion

Methods: Ergonomic Risk Assessment

Video Analysis

We focused our evaluation and job assessments on the ergonomic risk factors related to upper body activity, and specifically hand and wrist activity. We collected videos of each task listed in Table C1. We chose one employee to record for each job task based on convenience. We recorded one video for each job task that was long enough to see multiple work cycles. Videos were used to document the jobs for assessment by multiple raters [ACGIH 2025].

After the site visits, three National Institute for Occupational Safety and Health (NIOSH) ergonomists reviewed the videos and independently scored the repetition and force for each job task. We used the following approach:

- To assess repetition, we used the hand activity level scale to separately rate repetitiveness for right and left hands during at least five complete work cycles.
- To assess force, we separately rated peak exertion of the right and left hands using the modified Borg CR-10 scale [Borg 1982].
- To address ratings that differed between the NIOSH ergonomists, we discussed our observations and came to a joint decision.

We compared our measurements of hand activity and force with the action limit (AL) and threshold limit value (TLV®) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH®) [ACGIH 2025]. The TLV uses the average hand activity level and peak hand force to determine conditions where it is believed that nearly all employees can be exposed repeatedly without adverse health effects [ACGIH 2025]. This TLV was shown to be effective in protecting employees in a cohort study who performed hand intensive tasks from risk of carpal tunnel syndrome [Yung et al. 2019].

For each employee, we calculated a corresponding threshold normalized peak force (*NPF*) for the TLV and the AL using the observed Hand Activity Level (HAL_{OBS}) and the following equations:

$$NPF_{TLV} = 0.56*(10 - HAL_{OBS})$$

$$NPF_{AL} = NPF_{TLV} - 2$$

We then calculated a peak force index (*PFI*) for the TLV and AL using the following equations. NPF_{OBS} is the observer-rated peak exertion listed above.

$$PFI_{TLV} = \frac{NPF_{OBS}}{NPF_{TLV}}$$

$$PFI_{AL} = \frac{NPF_{OBS}}{NPF_{AL}}$$

We then used the PFI_{TLV} and PFI_{AL} to categorize tasks into the following three categories:

- Below the AL (Exposure Group 1): PFI_{AL} between 0 and 1.
- Between the AL and TLV (Exposure Group 2): PFI_{AL} greater than 1 or negative and PFI_{TLV} between 0 and 1.
- At or above the TLV (Exposure Group 3): PFI_{TLV} greater than 1 or negative.

Ratings and calculations were made for each hand separately. If categorization differed by hand, we assigned the task to the higher exposure group.

Force Gauge in the Hog Cooler

Hogs were transported throughout the facility on an automated, overhead conveyor system. The conveyance system was mostly automated. Two exceptions were when the hog carcasses were moved from the evisceration line into the cooler bays and when the cooled hog carcasses were moved from the cooler bays onto the conveyor to the further processing side of the facility. The main tasks for employees in the hog cooler were to (1) push hogs from the harvesting side of the plant into the bays of the hog cooler and (2) pull hogs out of the hog cooler and onto the conveyor for further processing.

The video analysis method described above was not appropriate for evaluating push and pull tasks within the hog cooler, though those tasks required visible exertion by employees. The characteristics of the pushing task (e.g., how employees engaged with the hog) and the physical properties of the force gauge (e.g., narrow plate, weight of the gauge, and positioning of the handlebars) made it impossible to measure the pushing force. Instead, we focused on evaluating the pull forces when employees removed hogs from the cooler bays.

A force gauge PSH 400 (IMADA, Inc., Northbrook, IL) was used to measure force exerted when moving hogs from the cooler bay onto the conveyor line for further processing. The gauge was tied to the meat hook tool that was used by employees. Employees were instructed to pull on the gauge in the same manner as when they pulled using the meat hook. Seven employees were assigned to work in the hog cooler during our visit. Of these, three were pulling or pushing hogs, and one was operating a forklift to assist with moving each row of hogs along the bay to the transfer point.

Results: Ergonomic Risk Assessment

Video Analysis

We analyzed videos from 51 tasks throughout the harvesting side of the facility (Table C1); 8/51 (16%) tasks were categorized as Exposure Group 3; 23/51 (45%) tasks were categorized as Exposure Group 2; and 20/51 (39%) tasks were categorized as Exposure Group 1.

Force Gauge in the Hog Cooler

We measured the pull forces of three employees two times each to better understand the types of force required to perform this task. Each employee pulled four hogs at a time. Each employee began the pull by walking backwards and then sideways once the hogs began moving along the rails. The distance pulled varied for each pull but ranged from approximately 10 to 20 feet in distance. Employees took turns performing this task so each employee would be responsible for pulling every third set of four hogs. Force ranged 52.5–80.0 foot-pounds, and the vertical hand height was approximately 53 inches. Although the employees' heights varied by about 6 inches, the meat hook tool was placed in approximately the same location on the hanging hog resulting in similar vertical hand heights.

Methods: Peracetic Acid Spray Cabinet Exposure Assessment

We collected area air samples for PAA, acetic acid, and hydrogen peroxide from two locations near the PAA spray cabinet. We also collected temperature and relative humidity measurements. The first area sampling location was at the mouth of the spray cabinet. The second area sampling location was an elevated work platform adjacent to the spray cabinet where one employee was stationed. A tripod was deployed at each sampling location and held all sampling equipment.

Acetic Acid

We collected full-shift area air samples for acetic acid from the platform location on 4 days and the cabinet location on 3 days. Samples were collected and analyzed using OSHA Method PV2119 [OSHA 2023] with a nominal airflow rate of 0.20 liters of air per minute.

Hydrogen Peroxide and PAA

We collected short-term area air samples for hydrogen peroxide and PAA from the cabinet sampling location on one day and from the platform sampling location on two days. We collected samples simultaneously using both a treated silica gel tube (SKC #226-199-UC) and a 25-millimeter cassette with treated filters (SKC #225-9030) in-line with a nominal flow rate of 1.0 liter of air per minute. Samples were analyzed using an in-house method from the NIOSH contract laboratory based on the Hecht et al. method [2004].

Additionally, we measured PAA for the entire shift in both sampling locations on four days using a ChemDAQ, Inc. SafeCide™ direct reading instrument (Pittsburgh, PA). Measurements were logged by the instrument every 2 seconds.

Temperature and Relative Humidity

We measured temperature and relative humidity using an Onset® HOBO® Pro V2 temperature and relative humidity data logger (Bourne, MA) on 4 days. Measurements were recorded every 15 minutes for the duration of the workday.

Results: Peracetic Acid Spray Cabinet Exposure Assessment

Acetic Acid

The sampling results are presented in Table C2. Area air samples for acetic acid ranged from 0.063 to 0.10 ppm for the cabinet sampling location and from 0.031 to 0.13 ppm for the platform sampling location across the three sampling days. OSHA, NIOSH, and ACGIH do not have occupational exposure limits (OELs) for area air samples.

Hydrogen Peroxide and PAA

The hydrogen peroxide sampling results for the cabinet and platform sampling locations are presented in Tables C3 and C4, respectively. We did not detect hydrogen peroxide in short-term area air samples for the cabinet sampling location. Concentrations ranged from not detected (ND) to 0.094 ppm for the platform sampling location. OSHA, NIOSH, and ACGIH do not have OELs for area air samples.

The short-term air sampling results for PAA at the spray cabinet and platform sampling locations are presented in Tables C3 and C4, respectively. The average concentration of PAA at the spray cabinet sampling location was 0.025 ppm (range: ND–0.035 ppm) on Day 2. The average concentrations of PAA at the platform sampling location on Days 3 and 4 were 0.011 ppm (range: ND–0.021 ppm). OSHA, NIOSH, and ACGIH do not have OELs for area air samples.

PAA concentrations recorded by the direct reading instrument are presented in Table C5. The average concentrations of PAA at the spray cabinet sampling location were 0.03 ppm (range: −0.05–0.27 ppm), 0.02 ppm (range: −0.06–0.40 ppm), 0.02 ppm (range: −0.04–0.39 ppm), and 0.03 ppm (range: −0.21–0.38 ppm) on Days 1, 2, 3, and 4, respectively. The average concentrations of PAA at the platform sampling location were 0.02 ppm (range: −0.66–0.31 ppm), −0.01 ppm (range: −3.7–0.28 ppm), 0.00 ppm (range: −0.12–0.05 ppm), and 0.00 ppm (range: −0.25–0.30 ppm) on Days 1, 2, 3, and 4, respectively. Of note, measurements showed negative concentrations, typically at the beginning of each day. It is unclear why this was happening, and discussions with the instrument manufacturer have not provided a solution at this time. One possibility is that both the instrument sensors and data logger should be turned on for a period of time (a "warm-up") prior to sampling.

Temperature and Relative Humidity

Results for temperature and relative humidity are displayed in Table C6. Temperature ranged 46°F–69°F and relative humidity ranged 49%–89% at the sampling location near the mouth of the spray cabinet. At the sampling location on the elevated work platform, temperature ranged 48°F–69°F and relative humidity ranged 52%–91%.

Methods: Engineering Control Evaluation

We evaluated the ventilation system that was connected to the PAA spray cabinet. There is no standard methodology to evaluate the effectiveness of local exhaust ventilation. However, we used traditional ventilation evaluation techniques to learn about how the system was functioning. We observed four exhaust ventilation columns, one at each corner of the cabinet. Each column was connected to an exhaust duct that exhausted the air outside of the workplace. Each column had one long slot that ran the length of the exhaust duct (and length of the spray cabinet) to provide distributed exhaust capture. We measured the slot dimensions and exhaust air velocity of all accessible slots to better understand how air was moving inside the cabinet. We took three air velocity measurements along the length of each slot, running the height of the ventilation duct using a TSI® Q-Trak with a hot wire probe (Shoreview, MN). We averaged those three measurements to determine an average exhaust slot velocity for each exhaust column.

All measurements were performed at the end of a shift when no hogs were moving through the spray cabinet. Maintenance turned off the PAA spray while leaving the ventilation system running for the engineering control evaluation.

Results: Engineering Control Evaluation

Hogs passed between the columns and were sprayed by a PAA solution from misters located on either side of the cabinet. There were eight PAA spray nozzles on each side of the cabinet. There was one long 0.75-inch slot that ran the full length of the exhaust duct column in each corner of the spray cabinet. These ducts exhausted air from the cabinet to capture and remove disinfectant vapor and mist. We found that average exhaust slot air velocity for each of the exhaust air columns ranged 92–167 feet of air per minute. Individual exhaust air velocities along the full slot length ranged 10–190 feet of air per minute.

PAA spray was observed to be leaking mostly out of the downstream side of the spray cabinet, likely being dragged out by the hogs and conveyor flow.

Methods: Review of Injury and Illness Protocols & Records

We reviewed facility injury and illness protocols and records.

Injury & Illness Protocols

We reviewed protocols that described the services available to employees reporting an injury or illness. Services included those available through the occupational health unit (OHU) and athletic trainer certified unit (ATCU). We also spoke with OHU and ATCU staff to understand each unit's scope of practice and how protocols were implemented.

OSHA 300 Logs

We reviewed information from OSHA Form 300 and 300A Log of Work-Related Injuries and Illnesses (OSHA Logs) reported for May 2018–December 2021. The plant operated on a fiscal year (FY) that ran May 1–April 30. Therefore, this period covered FY 2019 through the first 35 weeks of FY 2022. We summarized reported injuries and illnesses by FY of occurrence, nature, and body part affected. Plant management provided estimates of total hours worked by all harvesting side employees during each FY.

The OSHA Recordkeeping standard (29 CFR 1904) dictates that injury and illness reporting be done by calendar year; however, we did not have the needed information to calculate injury and illness rates to do so. Instead, for this evaluation, we calculated incidence rates of injuries and illnesses by FY of occurrence using the method described by OSHA [BLS 2019]. We then compared plant incidence rates with incidence rates for the North American Industry Classification System (NAICS) codes for animal slaughtering (except poultry) and processing (NAICS 311611) from the closest calendar year [BLS 2022].

We estimated incidence rates for (1) total injuries and illnesses, (2) injuries and illnesses resulting in days away from work, job restriction, or job transfer (DART), and (3) upper body musculoskeletal disorders resulting in DART. We defined an upper body musculoskeletal disorder as a report of an injury or illness to the upper body (i.e., neck, back, shoulders, elbows, wrists, hands, and fingers). We recorded the nature of the injury or illness as "Disorders associated with repeated trauma" or as the diagnosis if it was one listed in Table C7 [BLS 2023; NIOSH 1989, 1990, 2024]. We focused on upper body musculoskeletal disorders because the nature of the work, previous evaluations, and our ergonomic assessments of job tasks indicated that ergonomic risks for the upper body were of most concern.

Occupational Health Unit Logs

We reviewed electronic versions of logs from the plant's on-site OHU for June 2020–December 2021; only visits for an injury or illness were included in the logs provided. Unit logs included the injury or exposure date, employee's ID number, employee's department and job title, a description of the injury or illness, the nature of the injury or illness, and an employee statement about the injury or illness. We summarized visit characteristics using counts and percentages.

Athletic Training Encounter Logs

We reviewed electronic versions of athletic training logs for June 2020–December 2021. Logs included report date, employee's ID number, employee's department and job title, body part affected, designation of whether the injury was work-related, description of the complaint, description of posture problems identified, root cause of the problem, a rating of discomfort, and disposition. We summarized visit characteristics using counts and percentages.

Results: Review of Injury and Illness Protocols & Records

Injury & Illness Protocols

The OHU and ATCU were run by a contractor that provided both occupational health services and athletic training services on-site. The OHU also provided some primary care services, although these services were billed separately. Athletic trainers performed routine duties such as adjusting platforms, teaching stretches during new employee orientation, leading group stretching sessions by department, and making visits to the production floor to observe and assess work or to address a concern.

For acute injuries, employees were sent to the on-site OHU where staff evaluated the injury, provided first aid if needed, and referred the employee to either an occupational medicine physician, physician assistant, physical therapist, or emergency care as needed. OHU staff also reported that they followed up with employees after an acute injury to assess additional needs.

If an employee reported symptoms of a chronic injury or illness, the employee was first sent to the ATCU where a trainer performed an initial evaluation. If symptoms were considered discomfort and there was no indication of need for immediate medical care, trainers worked with the employee in daily visits for up to 96 working hours to identify a cause and provide treatment (i.e., stretching, use of heat and cold therapies, massage) to relieve the discomfort. The employee was referred to the OHU for further assessment and care if (1) no improvement occurred during the 96 hours working with the ATCU, (2) findings indicated the need for medical care, or (3) the employee requested to be seen by the OHU.

OHU staff assessed injuries and illnesses and referred employees for physical therapy or sent the employee for an evaluation by a clinician (i.e., physician assistant, occupational medicine physician). Athletic trainers sometimes were present during initial evaluations to offer the treating clinician knowledge of production jobs, potential mechanisms of injury, and the applicability of work restrictions. The clinician provided treatment, wrote work restrictions, documented actions in an online tracking system, scheduled in-house follow-up care, and worked with the case manager to identify and schedule any outside appointments with specialists. The OHU case manager followed employees referred to outside specialists to manage care. Although this was the typical approach, OHU staff described flexibility in how the process worked.

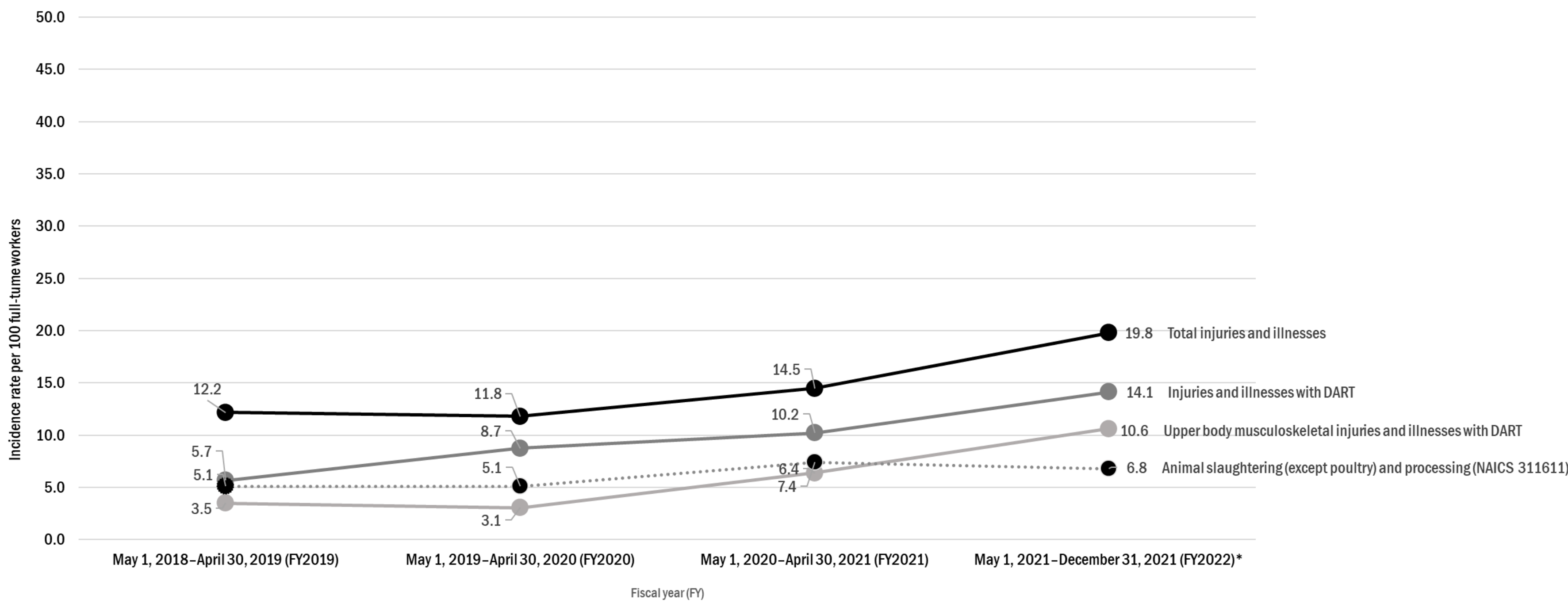
To track injuries and illnesses, the OHU case manager documented initial OSHA recordability determinations, and the safety manager verified information later to document OSHA recordable conditions. The OHU and ATCU also reported reviewing their own records regularly. The OHU held a morning meeting where injuries, illnesses, and near misses were discussed. Staff reported that the frequency of injuries and illnesses seen by the OHU were provided to management on a weekly basis. Statistical reports on OHU workload were sent from the company's headquarters location.

At the time of our visit, OHU staff also described handling routine employee testing requirements, which included vision, hearing, and drug screenings. They also provided in-house pulmonary function testing and respirator fit testing, and vaccines (e.g., flu, tetanus).

OSHA 300 Logs

A total of 117 injuries or illnesses were reported on the OSHA Logs as occurring during May 1, 2018–December 31, 2021 (Table C8). Most injuries and illnesses (n = 74, 63%) occurred to the upper extremities including the shoulders, elbows, hands, wrists, and fingers. Sprains, strains, and tears (n = 29; 25%) and disorders associated with repeated trauma (n = 29; 25%) were the most common injury or illness types, followed by cuts, lacerations, and punctures (n = 26; 22%). Of the 29 reports of disorders associated with repeated trauma, tendonitis or tenosynovitis accounted for 16 reports (55%), carpal tunnel syndrome accounted for 9 reports (31%), and epicondylitis accounted for 4 reports (14%). All reports of tendonitis or tenosynovitis were for stenosing tenosynovitis (trigger finger). Although rarely reported, fractures, dislocations, and crush injuries resulted in the largest number of days away from work (median: 240 days). Carpal tunnel syndrome also resulted in a median 104 days away from work.

During May 1, 2018–December 31, 2021, incidence rates of injuries and illnesses among harvesting side employees reported to OSHA increased and were typically higher than rates reported for the animal slaughtering (except poultry) and processing industry overall (Figure B1). Incidence of all reported injuries and illnesses increased from 12.2 to 19.8 injuries and illnesses per 100 full-time employees. Injuries and illnesses resulting in DART increased from 5.7 to 14.1 per 100 full-time employees. More than a third of the injuries and illnesses reported were upper body musculoskeletal injuries and illnesses. Annual incidence rates for upper body musculoskeletal injuries and illnesses resulting in DART ranged from 3.1 to 10.6 per 100 full-time employees. In comparison, total injury and illness rates for the animal slaughtering (except poultry) and processing industry during the same period ranged from 5.1 to 7.4 per 100 full-time employees depending on the year.



Incidence rates represent the number of injuries and illnesses per 100 full-time workers and were calculated as (N × 200,000)/EH, where N = number of injuries and illnesses, EH = total hours employee hours worked, and 200,000 = base for 100 equivalent full-time workers (working 40 hours per week, 50 weeks per year).
***FY2022 is a partial year**

Figure B1. Incidence rates of (1) total reported injuries and illnesses, (2) reported injuries and illnesses resulting in days away from work, job restriction, or job transfer (DART), and (3) reported upper body musculoskeletal disorders resulting in DART among harvesting side employees compared with (4) total injury and illness rates for the animal slaughtering (except poultry) and processing industry (NAICS 311611), May 2018–December 2021 (FY2019–partial FY2022).

Occupational Health Unit Logs

During June 2020–December 2021, 169 visits for injuries and illnesses occurred: 146 (86%) were to the upper body, 18 (11%) to the lower body, 3 (2%) were to both the upper and lower body, and 2 (1%) were to an unknown area. Employees whose job title was trimmer accounted for the most visits (n = 71; 42%), followed by animal handlers (n = 19; 11%) and master butcher harvest (n = 17; 10%). Employees from the clean harvest area accounted for 53% of visits (n = 90), while the barn/serpentine, wet harvest, and offal areas accounted for smaller proportions of visits (12%, 15%, and 20% respectively).

Athletic Training Encounter Logs

During June 2020–December 2021, athletic trainers conducted 245 consultations: all were recorded as occupationally-related issues. Most consultations were for issues involving the upper body (n = 240; 98%). Of the 245 consultations, 109 (44%) were for employees in the clean harvest area, 93 (38%) were for employees in the offal area, 38 (16%) were for employees in the wet harvest area, and 4 (2%) were for employees in the barn area. Most consultations were for employees with the job title Trimmer (n = 132; 54%) followed by Gambrellers (n = 29; 12%) and Butcher/Master Butcher (n = 26; 11%). Records indicated that of the 245 encounters, 203 consultations (83%) resolved the issue while 42 consultations (17%) required referral to the OHU. The root cause of approximately 62% of encounters was listed as "poor work tolerance." "Poor acclimation" and "Technique issue" were causes listed for 11% of encounters each.

Methods: Assessment of Musculoskeletal Symptoms and Disorders Through Employee Interviews

Sample Selection

During the first site visit, we informally and confidentially interviewed a convenience sample of employees from each job title in various harvesting side departments. We asked open-ended questions to learn more about their work, workplace, and health and safety concerns. We used these interviews to inform our assessment during the second visit.

During the second visit, we conducted confidential, structured interviews with a stratified random sample of approximately 25% of harvesting section employees (about 50 employees). To select the sample, we used the company's roster of all harvesting side employees scheduled to work during the week of our visit (n = 201), provided in advance by plant management. We organized the roster by department and job title and then generated a random single digit number. Employees in the position corresponding to the random number were selected from each department until we had a sample proportional to the total size of the department. We selected a total of 60 employees in case a selected employee was on leave or otherwise unavailable to participate. Once the random sample was selected, we examined the job title distribution to make sure most job titles were represented.

Employee participation in interviews was voluntary. All selected employees present at the worksite during the visit met with a NIOSH interviewer to either provide verbal consent and participate in an interview or decline participation in an interview. NIOSH staff conducted interviews in English, Spanish, and French. A phone-based, real-time translation service assisted in translating in Haitian

Creole and other languages, depending on the employee's preference. Through the structured interviews, we collected information about the employee's work history and work activities, employee perception of hand activity levels and force, musculoskeletal symptoms and conditions, relevant medical history, job concerns, and demographics.

Statistical Analysis

We described demographics and work characteristics of interview participants using frequencies and percentages or medians and ranges. We estimated the prevalence of self-reported, work-related musculoskeletal symptoms during the past 12 months and work-related, upper body musculoskeletal injuries or illnesses.

We defined work-related musculoskeletal symptoms as self-report of one or more symptoms (pain, numbness, tingling, aching, stiffness, or burning) in one of the following upper body areas (neck, upper and lower back, shoulder, elbow, wrist, or hand), which met all the below criteria [NIOSH 1997, 2019]:

- Symptoms lasted a whole day or more within the past year (or since beginning work at the plant if less than a year ago).
- Symptoms were not related to an acute accident or sudden trauma.
- Symptoms of the condition began or worsened after starting work at the plant.
- Symptoms occur after or are worsened by work activities.

We defined self-reported, work-related, upper body musculoskeletal injury or illness as an employee reported diagnosis by a healthcare provider of one or more conditions listed in Table C7, affecting one of the following upper body areas (neck, upper and lower back, shoulder, elbow, wrist, or hand), and met the below criteria:

- Self-reported diagnosis occurred, or symptoms worsened after starting work at the plant.
- Symptoms of the condition occur or are worsened by work activities.

These case definitions were derived from definitions used in scientific literature and previous NIOSH evaluations [BLS 2023; NIOSH 1989, 1990, 1997].

We used Poisson regression models with a robust variance estimator [Spiegelman and Hertzmark 2005] to estimate the prevalence and 95% confidence intervals (CIs) of outcomes overall and stratified by body part (i.e., neck, shoulders, upper and lower back, elbow, wrist/hand) and work characteristics, including work area, job title, and job tenure. If models did not converge because of small numbers, we estimated approximate CIs for binomial proportions using EpiSheet [Rothman and Boice 2012]. Because of small numbers, we were not able to adjust estimates for other factors (e.g., demographic variables such as age, or other work characteristics); instead, we present the unadjusted estimates in this report.

To better understand the burden of self-reported, work-related musculoskeletal symptoms and disorders among all harvesting side employees, we estimated and applied sampling weights as inverse probability weights to the sample of workers who were interviewed [Lash et al. 2021]. The sampling rate is calculated as the number of employees who worked in a specific department and job title who participated in an interview divided by the total number of employees in that department and job title.

$$\frac{1}{sampling\ rate\ given\ department\ and\ job\ title}.$$

This approach allowed interview participants to be weighted to represent themselves and employees working in the same department with the same job title who did not participate in an interview.

Finally, we reviewed and analyzed text responses to open-ended questions about employees' health and safety concerns at work. We looked for keywords and concepts and reported the frequency of identified themes. Data analysis was done using SAS Version 9.4 (SAS Institute Inc., Cary, NC). We applied survey weights using SAS survey procedures.

Results: Assessment of Musculoskeletal Symptoms and Disorders Through Employee Interviews

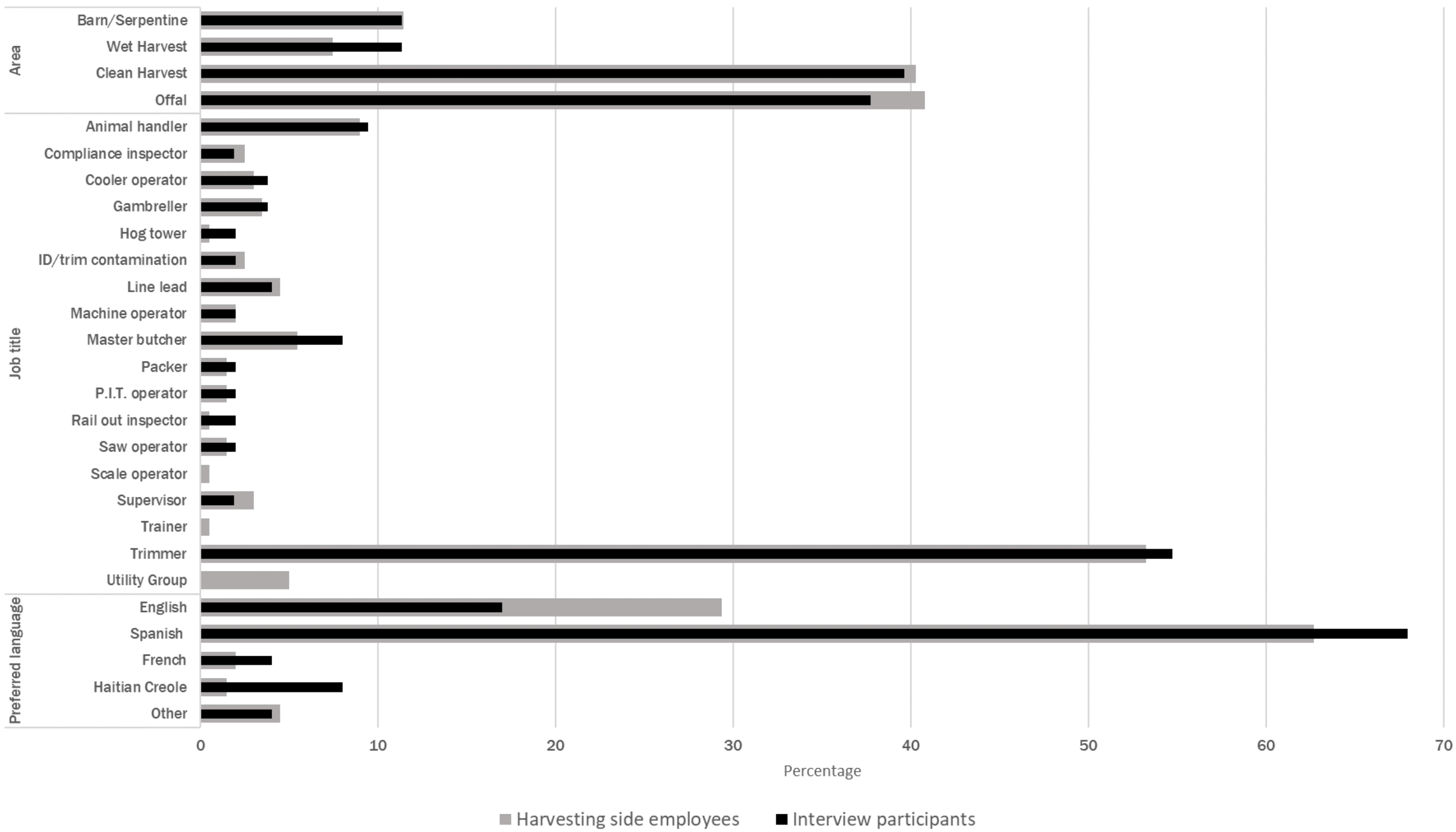
Demographics

A total of 53 employees participated in a confidential interview: 87% of interview participants were male, and participants had a median age of 47 years (range: 22–64 years). Participants identified as White (8%), African American or Black (11%), Asian (<10%), and American Indian or Alaska Native (<10%). Of the 53 employee participants, 68% identified as another race including African, Haitian, Central American, Latin/Latina/Spanish/Mexican American, and other specific countries of origin. Some participants described their race as good, strong, intelligent, humble, or hard working, indicating that race may not be thought of in the same way across multiple cultures or participants.

In total, 75% of participants considered themselves Hispanic and 25% considered themselves non-Hispanic. A majority of interview participants preferred to communicate in Spanish (68%), while 17% preferred English, 8% preferred Haitian Creole, <10% preferred French or another language (Figure B2). The distribution of preferred languages among interview participants was similar to the distribution of preferred languages included on the roster of all harvesting side employees used to select the sample.

Work Characteristics

Interview participants reported working at the plant for a median of 4 years (range: <2 months–>30 years). Participants reported working a median of 10.5 hours/day (range: 8–12.5 hours), 5.5 days/week (range: 5–6 days). As intended by the sample selection methods used, interview participants represented all harvesting side work areas and most job titles (Figure B2). A few job titles that existed among harvesting side employees were not represented by interview participants; these included scale operator, trainer, and utility group. Excluding these job titles, the proportion of interview participants from each work area and job title was proportional to the size of the work area and job type based on the roster. This indicated that the sample selected represented the entire harvesting side except those performing the job titles with no interview participants. Neither roster nor interview information allowed us to evaluate employees by job task as was done in the ergonomic assessment. Therefore, we present the remainder of the results in this section by work area (barn, wet harvest, clean harvest, offal) and job title.



P.I.T. = Powered industrial truck

Figure B2. Work area, job title, and preferred language among interview participants (black bars) compared with the total harvesting side employee population (gray bars). Black and gray bars are similar in length for most categories indicating that the interview participants represent harvesting side employees based on these characteristics. For example, 11% of harvesting side employees and interview participants work in the barn/serpentine work area.

Prevalence of Musculoskeletal Symptoms and Conditions

Musculoskeletal symptoms, including pain, numbness, tingling, burning, stiffness, and weakness, were common among interview participants: 83% (95% CI: 74%, 94%) of interview participants (n = 44) reported experiencing at least one of these symptoms during the previous 12 months (Table C9).

When we considered work-relatedness, 38% (95% CI: 27%, 53%) of interview participants (n = 20) reported experiencing a work-related symptom during the past 12 months (Table C9). All of them reported pain while other symptoms were reported less frequently, including stiffness (n = 6), numbness (n = 6), weakness (n = 3), tingling (n = 2), and burning (n = 2). The most common body parts affected were the right wrist/hand (25%), left wrist/hand (15%), and right shoulder (11%).

The prevalence of work-related symptoms was highest in the clean harvest area (n = 11/21 interviewed employees; 52%), followed by wet harvest (n = 2/6 interviewed employees; 33%) and offal (n = 6/20 interviewed employees; 30%). Work-related symptoms did not appear to substantially differ among males vs. females or by age, ethnicity, or preferred language, nor did the prevalence differ by work-related characteristics including years working at the plant, hours worked per week, or use of tools (results not shown).

After weighting the sample of employees participating in an interview based on job title and department, we estimated that approximately 70 employees or 39% (95% CI: 27%, 55%) of the harvesting side workforce performing the jobs in the departments represented by interview participants (approximately 181 employees) had experienced work-related musculoskeletal symptoms during the past 12 months (Table C9).

Approximately 28% of interviewed employees (n = 15) reported 30 musculoskeletal disorder diagnoses in their lifetime. Ten percent of interviewed employees (n = 6) reported 13 musculoskeletal disorder diagnoses that met the definition of work-relatedness. Work-related diagnoses included pinched nerve or herniated disc, sprain, tear, carpal tunnel syndrome, stenosing tenosynovitis of the fingers (trigger finger), epicondylitis, myalgia, rotator cuff injuries, and arthritis.

After weighting the sample of employees participating in an interview based on job title and department, we estimated that approximately 18 employees or 10% (95% CI: 4%, 22%) of the harvesting side workforce represented by interview participants (n = 181) had experienced a work-related musculoskeletal disorder diagnosis in their lifetime.

Employee Health and Safety Concerns

Of 47 responding employees, 26 (55%) reported that they find their job at least somewhat stressful. Specifically, responding employees noted the following as workplace stressors: the job in general, performing the same task for long hours, working in the heat, dealing with outdated facilities and equipment breakdowns, being short-staffed, and dealing with the line moving too fast.

Of 39 responding employees, 23 (59%) reported noticing changes during the past year that affected their job or safety and health concerns. Employees reported that after a chain speed increase, it was harder and more tiring to keep up with the work, they felt that they had to use tools more rapidly and that it was difficult for some people to keep up, and patience was required with training new people. Employees also reported that when the chain speed was decreased, they felt less pain in their hands and wrists. Employees reported that changes were made to the work area where guts are removed; these changes improved the work as the employee no longer needs to twist and throw the removed items; instead, they can drop the items into a trough under the line.

Most responding employees reported that if they had health and safety concerns, they would report them to their supervisor (n = 41/53; 77%). Other methods of reporting mentioned by at least one employee included via clinic or medical staff, human resources, management team, the appropriate department depending on the concern, and a team lead. The following current health and safety concerns were mentioned by employees: not receiving information about assessments that are done, pain from being stationary for too long or doing the same job all shift, injuries such as stab or puncture wounds, other people talking and interrupting concentration, hogs becoming stuck together before entering the cooler and needing to separate them, worn out rails making it harder to push hogs, the weight of the PPE making it difficult to wear, long-term health effects of exposure to hog waste, poor ventilation, and being able to access and use health insurance. Employees suggested the following to improve safety and health: improve communication with employees about how to work safely, pay more attention to what employees say are safety concerns, evaluate how many people are needed to run each area and make sure they are staffed appropriately, make sure hogs don't get stuck together on the line, reduce swinging of the hogs on the line, rotate workers between jobs more, provide the ability to take more time off to go to the doctor or do other personal things, improve ventilation, and reduce the pressure to work faster and increase focus on the job getting done correctly.

Methods: COVID-19 Protocol Review

We reviewed the company's written COVID-19 Assessment and Control Plan and compared it to CDC's recommendations at the time of the first visit (June 2021).

Results: COVID-19 Protocol Review

We summarized recommendations to improve the written COVID-19 Assessment and Control Plan in a letter provided to company management in July 2021.

Discussion

Employees in the animal slaughtering and processing industry face many workplace hazards [GAO 2005, 2016; NIOSH 2015; Ramos et al. 2021]. Work on a production line often involves repetitive and forceful motions, sometimes with awkward postures, performed at high speeds for long periods of time [GAO 2005, 2016; NIOSH 1990, 2015]. The ergonomic risks of this work put employees in danger of developing and worsening musculoskeletal disorders. Although injury and illness rates in the animal slaughtering and processing industry have declined since the early 2000s, they remain higher than rates for the manufacturing industry overall [GAO 2016].

Musculoskeletal disorders affecting the upper extremities are common among employees in the animal slaughtering and processing industry [Leibler and Perry 2017; OSHA 1993]. These disorders have a substantial effect on employees' ability to do their jobs and on their quality of life [Iqbal and Alghadir 2017]. Chemical exposures are also prevalent in the meat and poultry slaughter and processing environment [GAO 2016]. Specifically, PAA is used in the industry as a cleaning and sterilizing agent. It is applied to carcasses, parts, trim, and organs to reduce bacterial contamination [GAO 2016; USDA 2020]. This report covers an evaluation of potential ergonomic risks and PAA exposures in a pork slaughter and processing plant with a goal of providing recommendations to reduce related health and safety risks.

Ergonomics and Musculoskeletal Disorders

We used the ACGIH TLV for hand activity levels and force to characterize the ergonomic risk level of job tasks performed during the evisceration process [ACGIH 2025]. We found that of the 51 job tasks evaluated, 55% were above the ACGIH AL, and 16% were at or above the TLV. This means that a majority of job tasks are considered medium or high risk. This TLV, revised in 2018, has been validated and shown to predict a dose-response relationship for the incidence of carpal tunnel syndrome [Yung et al. 2019]. When the AL is exceeded, additional ergonomic controls should be employed [ACGIH 2025]. Therefore, many of the job tasks included in this evaluation should be further evaluated to identify interventions to reduce the risk to employees.

Implementing well-established interventions based on sound ergonomic principles is important in reducing the risk of work-related musculoskeletal disorders [NIOSH 2015]. Interventions should focus on reducing repetition, forceful exertions, and awkward and static postures [OSHA 1993, 2013]. Interventions should also prioritize hazard elimination and engineering controls whenever possible, consistent with the hierarchy of controls [NIOSH 2024a]. Specific interventions that have been demonstrated to reduce ergonomic risks include decreasing the speed at which work is performed, increasing the number of employees assigned to do a job, limiting overtime work, and providing more rest pauses. Automation of tasks can also reduce burden on employees. It is important to remember that changes to one task can have unintended consequences on other tasks. Therefore, when interventions are introduced, a re-assessment of potential risk factors for related tasks may be necessary.

Previous evaluations at meat and poultry plants that have applied the ACGIH TLV have also found large proportions of job tasks to be of medium or high risk (medium: 32%–62%; high: 31%–61%; total [medium or high]: 56%–92%) [NIOSH 1989, 2014, 2024b]. Job rotation is often recommended as an administrative control to reduce fatigue and stress of muscles and tendons by rotating employees to job tasks of lesser exposure or that use different muscle-tendon groups to reduce ergonomic risk factors [NIOSH 2014; OSHA 1993]. Job rotation was mentioned by management and employees, but no mandated job rotation program was adhered to regularly on the harvesting side of the plant. Rotating from higher exposure tasks to lower exposure tasks has been found to result in less fatigue and improved performance [NIOSH 2014; Raina and Dickerson 2009]. However, rotation among job tasks of similar exposure has not been found to reduce the risk of developing musculoskeletal disorders [Jonsson 1988]. Therefore, job rotation decisions should consider the ACGIH hand activity level TLV and AL. The TLV documentation states that it can be extended to multitask jobs by using time-weighted exposures [ACGIH 2025].

Another control used to reduce ergonomic risks is ensuring adequate breaks are provided. In the present plant, employees had regularly scheduled rest breaks. Tucker et al. [2003] found that limiting continuous work to less than 2 hours reduced risk of injury [NIOSH 2014]. Dababneh et al. [2001] found that hourly 9-minute breaks improved employee discomfort ratings without a negative effect on productivity. Under the current break schedule, employees are working continuously for more than 2 hours at times; adding more scheduled breaks would allow more rest, especially for those performing medium and high-risk jobs.

Based on OSHA 300 Logs, we found that the incidence of injuries and illnesses at this plant was higher than the national incidence reported for the animal slaughtering (except poultry) and processing industry (NAICS 311611). The plant incidence of upper body musculoskeletal injuries associated with job transfer or restriction increased from 3.5 to 12.0 per 100 full-time employees during May 2018–December 2021. During May 2018–April 2020, the incidence of upper body musculoskeletal injuries associated with job transfer or restriction was lower than the incidence of total injuries and illnesses in the industry overall (5.1 per 100 full-time employees). However, during May 2020–December 2021, the incidence of upper body musculoskeletal injuries associated with job transfer or restriction was higher than the incidence of total injuries and illnesses in the industry overall [BLS 2022].

This may reflect a true increase in the injury rate or may reflect the influence of other factors such as improvements to the medical program and ability to identify injuries and illnesses, changes in staffing, or the COVID-19 pandemic [GAO 2016]. Overall, rates were lower than those found in previous evaluations from the 1980s [NIOSH 1989] and a recent evaluation of a similar facility [NIOSH 2024b]. This reflects an overall reduction in injury and illness rates in the industry during the past several decades. However, it highlights the need for additional intervention.

Similar to our findings, previous evaluations at pork processing facilities found hands and wrists to be the most affected parts of the body, followed by elbows and shoulders. The most commonly reported diagnoses were tendonitis and strains or sprains [Leibler and Perry 2017; NIOSH 1989, 2024b]. More recent evaluations at pork and poultry processing facilities have found similar rates of injuries and illnesses resulting in time away from work as was seen at the present plant [Leibler and Perry 2017; NIOSH 2014, 2024b].

In interpreting these results, it is important to note that official estimates of injury and illness in the animal slaughtering and processing industry are considered underestimates, despite being twice that of general industry [Berkowitz et al. 2023; GAO 2005, 2016; Leibler and Perry 2017; Ramos et al. 2021]. Self-reported symptoms, injuries, and illnesses can provide a broader understanding of the musculoskeletal disorder burden in the workforce and may better reflect early symptoms of musculoskeletal disorders or conditions among employees that may go unreported [Leibler and Perry 2017].

In this evaluation, we found an estimated 39% of employees experienced symptoms consistent with work-related upper body musculoskeletal disorders during the year prior to our second visit: the hand or wrist was the most common body part affected. Previous evaluations have found a range of point prevalence estimates of symptoms and conditions, depending on the case definitions used and the population included in the questionnaire or interviews, and whether medical assessments were conducted [Leibler and Perry 2017; NIOSH 1989, 1990, 2014, 2015, 2024b]. Previous evaluations of point prevalence of symptoms within job task exposure categories have found that the prevalence of symptoms and musculoskeletal disorders of the upper body is higher in higher-risk jobs, as expected [NIOSH 1989, 1990].

With the identification of a majority of medium- and higher-risk jobs on the harvesting side, management has an opportunity to reduce the prevalence and severity of work-related musculoskeletal symptoms among the workforce by reducing hand activity levels and force of specific job tasks and implementing additional control measures. OSHA has developed ergonomics program management guidelines for the meatpacking industry that can serve as a foundation for identifying additional control measures [OSHA 1993]. More recent guidelines for the poultry processing industry also contain useful concepts and recommendations [OSHA 2013].

The medical management program at the plant met many of the recommendations included in OSHA's ergonomics program guidance [OSHA 1993, 2013]. OHU and ATCU records indicated that upper body injuries or illnesses were a common cause of seeking care at the plant. Records provided for this evaluation were detailed and management stated that records were regularly analyzed to identify trends over time and areas where intervention may be needed. However, it was not clear if injuries and illnesses could be easily tracked between the OHU, ATCU, and OSHA 300 records through resolution or what interventions have been implemented as a result of monitoring these data. In addition, ATCU records indicated "poor work tolerance" as the noted cause of most encounters with athletic trainers. This assertion places an emphasis on an individual worker's ability instead of on adjusting the work to fit the person (ergonomics). Such an interpretation could limit the identification and application of interventions to reduce health and safety risks for all workers assigned to a specific area or task.

Regular surveillance of injuries and illnesses is an important part of a program for identifying existing or potential problems [NIOSH 2015; OSHA 2013]. This includes reviewing OHU and ATCU records, OSHA Logs, and other logs that document injuries and illnesses (e.g., employees' compensation claims, insurance company reports, employee concern or problem reports). Systematic tracking of ATCU floor encounters and the dispensing of pain medications for work-related issues can help identify early signs of developing problems. When this information is combined with work details such as department, job title, and job task, it can help identify specific areas or groups where intervention may be beneficial.

Previous evaluations have demonstrated that the workforce in the animal slaughtering and processing industry recognized the health and safety risks of their jobs but felt that the environment made injury and illness inevitable [Ramos et al. 2021]. Feelings of inevitable injury or illness are important to recognize because it may deter workers from reporting symptoms early. Furthermore, research indicates that psychosocial factors (e.g., powerlessness, limited job control, low social support) play a role in the development of work-related musculoskeletal disorders of the upper body [NIOSH 1997].

Although most employees reported that they did not find their job stressful, some described various concerns about their health and safety at work. These concerns covered a range of topics including the speed of work, the repetition of work, and hogs becoming stuck. When asked about changes in the previous year that have affected their health and safety or concerns at work, multiple employees reported that increasing chain speed made their jobs more difficult or more dangerous and that decreases in line speed resulted in less pain in their hands or wrists. Increased line speed has been highlighted by others as an important factor that may lead to increases in ergonomic risks and musculoskeletal disorders among employees [GAO 2005, 2016]. In addition, employees provided solutions to consider, which focused on addressing some of the reported concerns. Seeking employee input when identifying control measures has been shown to lead to more effective interventions [OSHA 1993].

Our findings suggest the need for improving ergonomic interventions, processes, and injury and illness surveillance to reduce the burden of musculoskeletal disorders and related symptoms on employees. Reducing ergonomic risks and recognizing and intervening on musculoskeletal disorders early are key components of an employer's overall health and safety management program [OSHA 1993]. These actions can reduce the number of injured employees, severity of injury, days away from work, and likelihood of permanent physical damage [NIOSH 2014, 2015; OSHA 2013].

PAA

We used multiple methods to measure the components of the PAA solution made up of PAA, acetic acid, and hydrogen peroxide. OSHA, NIOSH, and ACGIH do not have OELs for area air samples. ACGIH has a short-term exposure limit (STEL) of 0.4 ppm PAA for worker exposures. However, we did not take personal samples during this evaluation for multiple reasons, mainly for the safety of employees and production considerations (i.e., the fast pace of production and sharp tools used by employees makes personal sampling on this scale less feasible than area sampling).

Our focus for this evaluation was to try to understand generally what the PAA spray cabinet was emitting. Area measurements taken on the platform cannot be directly compared with OELs because they were not personal breathing zone samples. However, these values may represent a reasonable approximation of potential exposures for employees who were stationed at fixed work locations near where we took the measurements. If an employee was exposed to these levels of PAA (ND–0.31 ppm), acetic acid (0.031–0.13 ppm), or hydrogen peroxide (ND–0.094 ppm) for the duration of their shift, they would likely not exceed the STEL set by ACGIH.

One notable phenomenon observed within the data from the direct reading instruments for PAA was the presence of negative values recorded at the beginning of each shift. Negative values have been observed in other NIOSH sampling efforts and noted when communicating with external companies with their own PAA direct reading monitors. We are not aware of documentation of this phenomenon in any published literature. Approximately 15 minutes after the instruments were deployed in the plant, the instruments began reading non-negative values. During the evaluation we tried turning the instrument sensors on 1–2 hours prior to collecting data at the worksite but still saw the same phenomenon on subsequent days. One possibility is that both the instrument sensors and data logger should be turned on for a period of time prior to sampling.

Our results do not indicate the need for further personal exposure monitoring for PAA, acetic acid, or hydrogen peroxide unless there are changes in the work process (e.g., amount being used, concentration being used, how it is being used, where it is being used). However, we know that employees report a wide range of symptoms when potentially exposed [Hawley et al. 2016; Hawley et al. 2017; NIOSH 2018], and the exposure assessment methodology is complicated [Hecht et al. 2004]. Be on the lookout for reports of irritation from employees working near PAA. This is especially important if either the application concentration of PAA or the number of application sites within the plant increases.

Because of the difficulty of measuring PAA in air, very little data are available in the published literature. In 2004, Hecht et al. published an article on the development of their analytical method for simultaneous measurement of PAA and hydrogen peroxide in air. The method was validated by taking 144 measurements in mineral water factories and hospital dispensaries [Hecht et al. 2004]. It was also used to measure exposures during equipment sterilization operations in a hospital [Dugheri et al. 2018].

In the Dugheri et al. study, researchers used multiple personal sampling methods, including the Hecht et al. [2004] method and a ChemDAQ direct-reading instrument, to measure PAA exposures during hospital endoscope disinfection processes. The different sampling methods showed good agreement [Dugheri et al. 2018].

In other research, NIOSH scientists conducted two health hazard evaluations (HHEs) among federal poultry inspectors in poultry processing facilities. In one 2014 HHE, all air samples for PAA using the Hecht et al. [2004] method were below the limit of detection [NIOSH 2016]. In the second HHE, while 55 ppm PAA solution was being used in the plant, researchers measured full-shift exposures of 0.0092 ppm and 0.008 ppm on two employees by collecting sequential short-term samples using the Hecht et al. method. The highest short-term sample collected was 0.019 ppm [NIOSH 2017]. Note that these exposures were taken on food safety inspectors and not on the poultry processing workers themselves, so they would not be representative of those workers.

An earlier assessment conducted at another pork processing plant showed PAA concentrations ranging ND–0.12 ppm from several short-term area samples (15–60-minute sampling times) over two days near a spray cabinet. Short-term area samples for hydrogen peroxide ranged ND–0.06 ppm for these locations [NIOSH 2024b].

A study of PAA exposures in four poultry processing plants was conducted by Houlroyd [2018]. These plants used PAA solutions ranging from 50 to 800 ppm in concentration. All samples analyzed for hydrogen peroxide were below the limit of detection. Sampling results for acetic acid were all less than 1 ppm. PAA samples collected and analyzed by the laboratory-based method ranged 0.037–0.54 ppm. Results for PAA using the real-time monitor ranged ND–0.339 ppm. The author recommended that further studies be conducted in poultry plant environments and that plant ventilation be assessed [Houlroyd 2018].

The engineering control evaluation helped to define a basic understanding of how air flowed within the PAA spray cabinet. We were unable to obtain design specifications for the system, so it was unclear how well the cabinet ventilation was performing compared with those specifications. Also, our ventilation measurements and observations may not accurately reflect actual conditions when hogs are moving through and being sprayed with PAA. Although further evaluation of the spray cabinet is not necessary, it is important to perform manufacturer-recommended maintenance on the system and periodically check to make sure the cabinet is operating as desired.

Strengths

The ergonomic risk assessment used the ACGIH TLV for hand activity level, which is a standardized and validated assessment tool. In addition, job tasks were reviewed by multiple ergonomists. Both the ergonomic assessment and the confidential interviews had a high participation rate. Good participation in confidential interviews was partly made possible by offering interviews in the employees' language of choice. In addition, those participating in an interview were a random sample of the harvesting side workforce selected by department. Good participation and a stratified random sample help ensure those who participate in the evaluation are a representative sample of the workforce, reducing concerns about selection bias. Finally, because we had information about job title and department for the whole workforce, we were able to estimate and apply survey sampling weights. This statistical method was used to estimate the burden of musculoskeletal symptoms and disorders in the harvesting side workforce based on the sample who were interviewed. This approach provides a more complete understanding of the total burden of these conditions.

Limitations

This evaluation was cross-sectional, meaning it measured hazards and outcomes at one point in time. Cross-sectional evaluations provide useful information that can inform recommendations for improving workplace safety and health. However, the healthy worker survivor effect is an inherent bias of the design. Employees who remain on the job (sometimes referred to as survivors) are usually healthier than those who have left employment. Because cross-sectional studies do not include former employees, some who may have left their job because they developed a musculoskeletal injury or illness, the healthy worker survivor effect can lead to an underestimate of the burden of musculoskeletal disorders and symptoms.

Given the high employee turnover rate in the industry, the burden of musculoskeletal symptoms and disorders among harvesting side employees is likely higher than what was found here. In addition, not all job titles were represented by interview participants; therefore, our findings may not be generalizable to all job titles in the harvesting section.

We were only able to calculate injury and illness rates based on FY. Depending on the occurrence of injuries and hours worked, rates calculated for a calendar year, as required by OSHA, may differ.

We were not able to assign the employees who were interviewed to ACGIH hand activity level exposure levels determined through video analysis. Video assessments and interviews were conducted at separate visits and, although we had job title information, we did not have reliable enough descriptions of the job tasks for interviewed employees to assign them to a job task and risk group.

The Hecht et al. [2004] method may underestimate exposures when PAA is applied as a spray. Additionally, industrial hygiene sampling and an engineering control evaluation can only document exposures and conditions on the days and in the locations evaluated. These results may not be representative of conditions during other days or on other work sites.

Although not a limitation of this HHE, it is important to note that the findings reported here are specific to this plant and may not be generalizable to other pork processing facilities.

Section C: Tables

Table C1. Risk assessment exposure groups based on the ACGIH Hand Activity Level TLV. Categories are presented by job task (n = 51) and work area

Work Area*	Task Name (n = 51)	Group†
Clean Harvest	Mouth washer	1
	Head clipper	1
	Incising lymph nodes	1
	De-bunger	1
	Opener	1
	Liver removal and gullet hang	1
	Whizard trim	1
	Head spiker	1
	Cheek release	1
	Load jaw removal machine	1
	Cheek trim	1
	Snout removal	1
	Snout cartilage removal	1
	Stomach removal	2
	Spleen removal	2
	Heart removal	2
	Aorta removal	2
	Liver hang low	2
	Low toe jam	2
	Head dropper	2
	Head hang	2
	Manual brisket saw	2
	Pull membrane	2
	Gutter	2
	Kidney popper	2
	Low trim	2
	Tail removal	2
	Leaf lard puller	2
	Tender trim	2
	Snout release	2
	Ear removal	2
	Tongue removal	3
	Tongue trim	3
	Kidney removal	3
	Final trim	3
Wet Harvest	Turn hog	2
	Stick	2
	Shackle	2
	Cord cut	3
	Gambreller	3
Offal	Pancreas removal final check	1
	Liver box seal	1
	Head pack final stage	1
	Spinal vacuum	1
	Intestine separation	1
	Intestine clean	1
	Intestine trim	1
	Liver pack	2
	Head pack	2
	Stomach puncture	3
	Pancreas removal	3

* Note that Barn/Serpentine and Cooler areas were not included in this analysis.

† Group 1: task is below the ACGIH action limit; Group 2: task is at or above the ACGIH action limit but below the TLV; Group 3: task is at or exceeds the ACGIH TLV.

Table C2. Full-shift acetic acid concentrations for each sampling location across four days

Day	Sample location	Sample duration (minutes)	Concentration (ppm)*
1	Platform	572	0.130
2	Cabinet	281	0.086
	Platform	538	0.031
3	Cabinet	485	0.063
	Platform	487	0.032
4	Cabinet	601	0.100
	Platform	601	0.039

ppm = parts per million

* The minimum detectable concentration ranged from 0.003 to 0.008 ppm. The minimum quantifiable concentration ranged from 0.009 to 0.026 ppm.

Two samples were removed (one full-shift sample from cabinet Day 1 and one approximately half-shift sample from cabinet Day 2) from the analysis due to a greater than 10% difference in pre- and post-sampling calibration airflow.

Table C3. Short-term area air sample results for peracetic acid and hydrogen peroxide for the cabinet sampling location on Day 2

Sample duration (minutes)	Peracetic acid (ppm)*	Hydrogen peroxide (ppm)†
20	0.035	ND
20	0.029	ND
20	[0.019]	ND
20	[0.015]	ND
20	[0.019]	ND
20	[0.021]	ND
20	[0.027]	ND
20	[0.019]	ND
20	0.029	ND
13	ND	ND
20	0.035	ND
20	0.029	ND
20	0.032	ND
20	0.030	ND
20	0.029	ND
20	[0.019]	ND
7	ND	ND
20	0.031	ND
20	0.034	ND
20	[0.024]	ND
20	[0.026]	ND
19	[0.029]	ND
20	[0.019]	ND
20	0.031	ND
21	0.028	ND
20	0.033	ND
20	0.029	ND
15	[0.028]	ND

ND = Not detected; ppm = parts per million

[ ] = Values shown in brackets are between the minimum detectable and minimum quantifiable concentrations. More uncertainty is associated with these concentrations.

* The minimum detectable concentrations ranged from 0.008 to 0.02 ppm. The minimum quantifiable concentrations ranged from 0.026 to 0.076 ppm.

† The minimum detectable concentrations ranged from 0.1 to 0.3 ppm. The minimum quantifiable concentrations ranged from 0.23 to 0.66 ppm.

Table C4. Short-term area air sample results for peracetic acid and hydrogen peroxide for the platform sampling location on Days 3 and 4

Day	Sample duration (minutes)	Peracetic acid (ppm)*	Hydrogen peroxide (ppm)†
3	20	[0.015]	ND
	20	[0.0091]	ND
	20	[0.013]	ND
	20	ND	ND
	20	[0.015]	ND
	20	[0.013]	ND
	20	[0.0080]	ND
	20	[0.019]	ND
	20	ND	ND
	20	[0.014]	ND
	20	[0.010]	ND
	20	[0.018]	ND
	20	[0.014]	ND
	20	[0.012]	ND
	20	[0.021]	ND
	20	ND	ND
	20	[0.014]	ND
	20	[0.014]	ND
	20	[0.014]	ND
	20	ND	ND
	20	ND	ND
	20	[0.0084]	ND
	20	[0.010]	ND
	20	[0.015]	ND
4	20	[0.018]	ND
	20	[0.014]	ND
	20	[0.0093]	ND
	20	[0.0095]	ND
	20	[0.018]	ND
	20	[0.015]	ND
	20	[0.012]	ND
	20	[0.014]	ND
	20	[0.014]	ND
	20	[0.012]	ND
	20	[0.014]	ND
	20	[0.0092]	ND
	20	ND	ND
	20	ND	ND
	20	ND	ND
	20	[0.011]	ND
	20	[0.0096]	ND
	20	[0.0089]	ND
	20	[0.013]	ND
	20	[0.019]	ND
	20	[0.010]	ND
	20	[0.014]	ND
	20	[0.0096]	ND
	20	[0.021]	ND
	20	[0.013]	ND
	20	[0.013]	[0.094]
	20	[0.017]	ND
	20	[0.013]	ND
	20	[0.0091]	ND
	20	ND	ND

[ ] = Values shown in brackets are between the minimum detectable and minimum quantifiable concentrations. More uncertainty is associated with these concentrations.
ND = Not detected; ppm = parts per million
* The minimum detectable concentration was 0.008 ppm on Day 3 and ranged from 0.008 to 0.009 ppm on Day 4. The minimum quantifiable concentrations ranged from 0.027 to 0.028 ppm on Day 3 and from 0.027 to 0.029 ppm on Day 4.
† The minimum detectable concentration was 0.1 ppm on Days 3 and 4. The minimum quantifiable concentrations ranged from 0.23 to 0.24 ppm on Day 3 and from 0.23 to 0.25 ppm on Day 4.

Table C5. Full-shift direct reading instrument results summary for peracetic acid for each sampling location across four days

Sampling location	Day 1 average [range]	Day 2 average [range]	Day 3 average [range]	Day 4 average [range]
Cabinet	0.030 [–0.05–0.27]	0.020 [–0.06–0.40]	0.020 [–0.04–0.39]	0.030 [–0.21–0.38]
Platform	0.020 [–0.66–0.31]	–0.01 [–3.7–0.28]	0.00 [–0.12–0.05]	0.00 [–0.25–0.30]

Table C6. Full-shift temperature and relative humidity measurements for each sampling location across four days

Day	Cabinet		Platform	
	Temperature °F [range]	Relative humidity % [range]	Temperature °F [range]	Relative humidity % [range]
1	47 [46–55]	84 [67–89]	49 [48–55]	78 [57–91]
2	53 [51–66]	77 [56–81]	51 [50–66]	80 [52–83]
3	54 [51–69]	72 [55–80]	55 [53–69]	72 [55–76]
4	51 [49–68]	51 [49–68]	50 [48–67]	79 [52–85]

Table C7. Diagnoses included in a case definition for musculoskeletal disorders used in the present evaluation*

Injury where the nature is a pinched nerve or herniated disc
Tendonitis
Sprain, strain, tear
Carpal or tarsal tunnel syndrome
Trigger finger, stenosing tenosynovitis of the fingers
de Quervain's tenosynovitis, stenosing tenosynovitis of the thumb
Tennis elbow, epicondylitis
Tenosynovitis
Myalgia, myositis
Neuralgia, neuritis of the ulnar nerve
Ulnar nerve entrapment (cubital tunnel syndrome)
Synovitis
Bursitis
Ganglion cyst
Rotator cuff injury
Costochondritis
Torticollis (cervical dystonia)
Arthritis
Raynaud’s syndrome or phenomenon
Other musculoskeletal and connective tissue diseases and disorders

* This list of conditions is consistent with the Bureau of Labor Statistics definition of musculoskeletal disorders in use since 2011 [BLS 2023] and has been used in previous evaluations [NIOSH 1989, 1990,1997, 2024b]. Some of these conditions can occur throughout the body; in this evaluation we focused on these diagnoses when they occurred in the upper body only.

Table C8. Nonfatal occupational injuries and illnesses occurring among harvesting side employees by part of the body affected and nature as reported on OSHA Logs, May 2018–December 2021

	May 1, 2018–April 30, 2019 (FY2019)	May 1, 2019–April 30, 2020 (FY2020)	May 1, 2020–April 30, 2021 (FY2021)	May 1, 2021–December 31, 2021 (FY2022)*	Total FY2019–2022*	
	n = 28	n = 27	n = 34	n = 28	n = 117	%
Part of the body affected						
Head	9	4	4	2	19	16
Neck	0	0	1	0	1	1
Trunk	5	2	3	2	12	10
Upper extremities	11	17	24	22	74	63
Lower extremities	3	4	2	2	11	9
Missing	0	0	0	0	0	0
Nature of injury or illness						
Amputations	0	0	0	0	0	0
Bruises, contusions	1	1	4	1	7	6
Burns	1	1	1	0	3	3
Cuts, lacerations, punctures	5	9	5	7	26	22
Fractures	0	1	1	0	2	2
Sprains, strains, tears	5	5	11	8	29	25
Soreness, pain	3	1	0	0	4	3
Disorders associated with repeated trauma	4	5	10	10	29	25
All other natures	9	4	2	2	17	15

* Partial year

Table C9. Self-reported prevalence of signs and symptoms of upper body musculoskeletal injuries during the last 12 months

		All symptoms			Work-related symptoms Sample			Work-related symptoms Weighted		
	Total participants	n	Prevalence (%)	95% CI	n	Prevalence (%)	95% CI	n†	Prevalence (%)	95% CI
Any symptom*	53	44	83	74, 94	20	38	27, 53	70	39	27, 55
Body part										
Neck	53	8	15	8, 29	2	4	1, 15	7	4	1, 15
Left shoulder	53	20	38	27, 53	5	9	4, 22	16	9	4, 21
Right shoulder	53	20	38	27, 53	6	11	5, 24	19	11	5, 23
Upper back	53	5	9	4, 22	4	8	3, 19	12	7	2, 19
Lower back	53	12	23	14, 37	3	6	2, 17	10	6	2, 19
Left elbow	53	2	4	1, 15	1	2	0, 13	3	2	0, 12
Right elbow	53	3	6	2, 17	0	0	—	0	0	—
Left wrist/hand	53	18	34	23, 49	8	15	8, 29	27	15	8, 29
Right wrist/hand	53	24	45	34, 61	13	25	15, 39	43	24	15, 39
Work area										
Barn	6	4	67	29, 90‡	1	17	3, 100	4	19	NC
Wet harvest	6	4	67	20, 90‡	2	33	10, 70‡	7	41	NC
Clean harvest	21	18	86	65, 95‡	11	52	35, 79	37	51	34, 79
Offal	20	18	90	70, 97‡	6	30	15, 59	23	32	16, 61

CI = confidence interval; NC = not calculated due to small numbers.

* Signs and symptoms reported included pain, tingling, burning, numbness, stiffness, and weakness.

† Weighted to represent the total population of harvesting side employees in the departments and job types represented by the interview participants. Sampling weights sum to 181.

‡ Approximate CIs calculated using EpiSheet [Rothman and Boice 2012].

Section D: Occupational Exposure Limits

NIOSH investigators refer to mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects.

However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a preexisting medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended STELs or ceiling values. Unless otherwise noted, the STEL is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- OSHA, an agency of the U.S. Department of Labor, publishes permissible exposure limits [29 CFR 1910 for general industry; 29 CFR 1926 for construction industry; and 29 CFR 1917 for maritime industry] called PELs. These legal limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH recommended exposure limits (RELs) are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2007]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, PPE, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Another set of OELs commonly used and cited in the United States includes the TLVs, which are recommended by the ACGIH. The ACGIH TLVs are developed by committee members of this professional organization from a review of the published, peer-reviewed literature. TLVs are not consensus standards. They are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2025].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at https://www.dguv.de/ifa/gestis/gestis-stoffdatenbank/index-2.jsp, contains international limits for more than 2,000 hazardous substances and is updated periodically.

OSHA (Public Law 91-596) requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions.

Section E: References

Methods

ACGIH [2025]. 2025 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

BLS [2019]. How to compute a firm's incidence rate for safety management. Washington, DC: U.S. Bureau of Labor Statistics, https://www.bls.gov/iif/overview/compute-nonfatal-incidence-rates.htm.

BLS [2022]. Table 1. Incidence rates of nonfatal occupational injuries and illnesses by industry and case types, 2018–2021. In: Industry injury and illness data, 2018–2021. Washington, DC: U.S. Bureau of Labor Statistics, https://www.bls.gov/iif/nonfatal-injuries-and-illnesses-tables/soii-summary-historical.htm.

BLS [2023]. BLS OSH definitions. Washington, DC: U.S. Bureau of Labor Statistics, https://www.bls.gov/iif/definitions/occupational-safety-and-health-definitions.htm.

Borg GA [1982]. Psychophysical bases of perceived exertion. Med Sci Sports Exerc *14*(5):377–381, https://doi.org/10.1249/00005768-198205000-00012.

Hecht G, Héry M, Hubert G, Subra I [2004]. Simultaneous sampling of peroxyacetic acid and hydrogen peroxide in workplace atmospheres. Ann Occup Hyg *48*(8):715–721, https://doi.org/10.1093/annhyg/meh067.

Lash TL, VanderWeele TJ, Haneuse S, Rothman KJ, eds. [2021]. Modern epidemiology. 4th ed. Philadelphia, PA: Lippincott Williams & Wilkins.

NIOSH [1989]. John Morrell and Co., Sioux Falls, South Dakota. By Hales T, Habes D, Fine L, Hornung R, Boiano J. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 1988-0180-1958, https://www.cdc.gov/niosh/hhe/reports/pdfs/1988-0180-1958.pdf.

NIOSH [1990]. Perdue Farms, Inc. Lewiston, North Carolina, Robersonville, North Carolina. By Kiken S, Stringer W, Fine L, Sinks T, Tanaka S. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 1989-0307-2009, https://www.cdc.gov/niosh/hhe/reports/pdfs/1989-0307-2009.pdf.

NIOSH [1997]. Musculoskeletal disorders and workplace factors: a critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 97-141, https://www.cdc.gov/niosh/docs/97-141/default.html.

NIOSH [2019]. Evaluation of musculoskeletal disorders and traumatic injuries among employees at a poultry processing plant. By Musolin K, Ramsey JG, Wassell JT, Hard DL, Mueller C. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2012-0125-3204, https://www.cdc.gov/niosh/hhe/reports/pdfs/2012-0125-3204.pdf.

OSHA [2023]. OSHA sampling and analytical methods. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration, http://www.osha.gov/dts/sltc/methods/index.html.

Rothman KJ, Boice JD Jr. [2012]. EpiSheet: spreadsheets for the analysis of epidemiologic data. Research Triangle Park, NC: RTI Health Solutions, https://www.rtihs.org/episheet.

Spiegelman D, Hertzmark E [2005]. Easy SAS calculations for risk of prevalence ratios and differences. Am J Epidemiol *162*(3):199–200, https://doi.org/10.1093/aje/kwi188.

Yung M, Dale AM, Kapellusch J, Bao S, Harris-Adamson C, Meyers AR, Hegmann KT, Rempel D, Evanoff BA [2019]. Modeling the effect of the 2018 revised ACGIH® Hand Activity Threshold Limit Value® (TLV) at reducing risk for carpal tunnel syndrome. J Occup Environ Hyg *16*(9):628–633, https://doi.org/10.1080/15459624.2019.1640366.

Discussion

ACGIH [2025]. 2025 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

Berkowitz D, Goff AD, Fagan KM, Gerrek ML [2023]. Do clinics in meat and poultry plants endanger workers? AMA J Ethics *25*(4):E278–E286, https://doi.org/10.1001/amajethics.2023.278.

Dababneh AJ, Swanson N, Shell RL [2001]. Impact of added rest breaks on the productivity and well being of workers. Ergonomics *44*(2):164–174, https://doi.org/10.1080/00140130121538.

Dugheri S, Bonari A, Pompilio I, Colpo M, Montalti M, Mucci N, Arcangeli G [2018]. Assessment of occupational exposure to gaseous peracetic acid. Int J Occup Med Environ Health *31*(4):527–535, https://doi.org/10.13075/ijomeh.1896.01166.

GAO [2005]. Workplace safety and health. Safety in the meat and poultry industry, while improving, could be further strengthened. Washington, DC: U.S. Government Accountability Office, GAO-05-96, https://www.gao.gov/assets/gao-05-96.pdf.

GAO [2016]. Workplace safety and health. Additional data needed to address continued hazards in the meat and poultry industry. Washington, DC: U.S. Government Accountability Office, GAO-16-337, https://www.gao.gov/assets/gao-16-337.pdf.

Hawley B, Casey ML, Cox-Ganser JM, Edwards N, Fedan KB, Cummings KJ [2016]. Notes from the field: respiratory symptoms and skin irritation among hospital workers using a new disinfection product—Pennsylvania, 2015. MMWR *65*(15):400–401, https://doi.org/10.15585/mmwr.mm6515a3.

Hawley B, Casey M, Virji MA, Cummings KJ, Johnson A, Cox-Ganser J [2017]. Respiratory symptoms in hospital cleaning staff exposed to a product containing hydrogen peroxide, peracetic acid, and acetic acid. Ann Work Expo Health *62*(1):28–40, https://doi.org/10.1093/annweh/wxx087.

Hecht G, Héry M, Hubert G, Subra I [2004]. Simultaneous sampling of peroxyacetic acid and hydrogen peroxide in workplace atmospheres. Ann Occup Hyg *48*(8):715–721, https://doi.org/10.1093/annhyg/meh067.

Houlroyd J [2018]. A pilot study of exposures to peracetic acid-based disinfectants among poultry processing workers. Abstract. Tucker, GA: U.S. Poultry Foundation, https://www.uspoultry.org/programs/research/search-abstracts/repository/BRU010.html.

Iqbal ZA, Alghadir AH [2017]. Cumulative trauma disorders: a review. J Back Musculoskelet Rehabil *30*(4):663–666, https://doi.org/10.3233/bmr-150266.

Jonsson B [1988]. Electromyographic studies of job rotation. Scand J Work Environ Health *14*(Suppl 1):108–109, https://www.sjweh.fi/article/1994.

Leibler JH, Perry MJ [2017]. Self-reported occupational injuries among industrial beef slaughterhouse workers in the Midwestern United States. J Occup Environ Hyg *14*(1):23–30, https://doi.org/10.1080/15459624.2016.1211283.

NIOSH [2014]. Evaluation of musculoskeletal disorders and traumatic injuries among employees at a poultry processing plant. By Musolin K, Ramsey JG, Wassell JT, Hard DL, Mueller C. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2012-0125-3204, https://www.cdc.gov/niosh/hhe/reports/pdfs/2012-0125-3204.pdf.

NIOSH [2015]. Evaluation of carpal tunnel syndrome and other musculoskeletal disorders among employees at a poultry processing plant. By Ramsey JG, Musolin K, Mueller C. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2014-0040-3232, https://www.cdc.gov/niosh/hhe/reports/pdfs/2014-0040-3232.pdf.

NIOSH [2016]. Assessment of peracetic acid exposure among federal poultry inspectors. By Burton, NC, Gibbins, J. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2014-0196-3254, https://www.cdc.gov/niosh/hhe/reports/pdfs/2014-0196-3254.pdf.

NIOSH [2017]. Evaluation of peracetic acid exposure among federal poultry inspectors. By Burton NC, Gibbins, J. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2015-0130-3290, https://www.cdc.gov/niosh/hhe/reports/pdfs/2015-0130-3290.pdf.

NIOSH [2018]. Evaluation of exposure to a new cleaning and disinfection product and symptoms in hospital employees. By Hawley B, Casey M, Cummings K, Edwards N, Johnson A, Cox-Ganser J.

Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2015-0053-3269, https://www.cdc.gov/niosh/hhe/reports/pdfs/2015-0053-3269revised092018.pdf.

NIOSH [2024a]. Hierarchy of controls. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, https://www.cdc.gov/niosh/hierarchy-of-controls/about/.

NIOSH [2024b]. Evaluation of ergonomic risks, musculoskeletal disorders, and peracetic acid exposure among employees at a pork processing plant in Michigan. By Grant MP, Rinsky JL, Dunn KH. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2021-0117-3397, https://www.cdc.gov/niosh/hhe/reports/pdfs/2021-0117-3397.pdf.

OSHA [1993]. Ergonomics program management guidelines for meatpacking plants. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration, OSHA 3123, https://www.osha.gov/publications/OSHA3123.

OSHA [2013]. Prevention of musculoskeletal injuries in poultry processing. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration, OSHA 3213-12R 2013, https://www.osha.gov/sites/default/files/publications/OSHA3213.pdf.

Raina SM, Dickerson CR [2009]. The influence of job rotation and task order on muscle fatigue: a deltoid example. Work *34*(2):205–213, https://doi.org/10.3233/wor-2009-0917.

Ramos AK, Carvajal-Suarez M, Trinidad N, Quintero SA, Molina D, Johnson-Beller R, Rowland SA [2021]. Health and well-being of Hispanic/Latino meatpacking workers in Nebraska: an application of the Health Belief Model. Workplace Health Saf *69*(12):564–572, https://doi.org/10.1177/21650799211016907.

Tucker P, Folkard S, Macdonald I [2003]. Rest breaks and accident risk. Lancet *361*(9358):680, https://doi.org/10.1016/s0140-6736(03)12566-4.

USDA [2020]. Health hazard information sheet: peroxyacetic acid (PAA). Washington, DC: U.S. Department of Agriculture, Food Safety and Inspection Service, https://www.fsis.usda.gov/sites/default/files/media_file/2020-08/Peroxyacetic-Acid.pdf.

Yung M, Dale AM, Kapellusch J, Bao S, Harris-Adamson C, Meyers AR, Hegmann KT, Rempel D, Evanoff BA [2019]. Modeling the effect of the 2018 revised ACGIH® Hand Activity Threshold Limit Value® (TLV) at reducing risk for carpal tunnel syndrome. J Occup Environ Hyg *16*(9):628–633, https://doi.org/10.1080/15459624.2019.1640366.

Occupational Exposure Limits

ACGIH [2025]. TLVs and BEIs: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

CFR [2023]. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register, https://www.ecfr.gov/.

NIOSH [2007]. NIOSH pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-149, http://www.cdc.gov/niosh/npg/.

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