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Using Participatory Ergonomics to Improve Health and Safety in Commercial Lobstering in the United States: 2 Case Studies

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Abstract

The lobster-harvesting industry has a high occupational injury incidence compared to land-based industries. Participatory ergonomics methods were used to partner with lobstermen to develop and implement ergonomic improvements. The model included training in ergonomics principles, a forum for ergonomics discussions, and a sequence of meetings planned to focus on problem identification, intervention, evaluation, and dissemination of findings. One crew initiated 3 specific actions: the introduction of a conveyor belt to assist material handling at a local lobstering pier, the installation of a star block at the space for hauling traps onto the boat, and the initiation of a design process for improved mechanical assistance for hauling traps onto the boat. The other crew took action to reduce force and postural exposures by creating a short video intended to disseminate ergonomic ideas to other lobstermen. The influence of important cultural norms was observed for future research and development in the community.

Keywords

participatory ergonomics, commercial fishing, manual material handling, musculoskeletal disorder, ergonomic intervention, fisheries

Introduction

Lobstermen of the coastal Northeast United States have one of the highest occupational injury incidence rates of any worker group,[1] and more needs to be done to understand practical solutions to improve the health and safety of this population. Our study addresses this critical gap in the scientific literature by utilizing a participatory ergonomics (PE) approach to working directly with the lobstermen. This report describes 2 case studies out of a larger series developed using this approach and describes policy implications for the commercial lobster industry.

Commercial Fishing Context

In contrast with most land-based labor, commercial fishing is differentiated from other maritime industries because work is defined not only by natural resources but by equipment and geopolitical boundaries, as well.[2,3] The constantly changing environment of commercial fishing labor is not limited to the physical environment. As Howard[2] explained it, commercial fishing labor can be characterized as metabolism of complicated interacting forces of the physical environment, socioeconomic relationships, and the fishermen's political economy.

Commercial Lobstering and Occupational Health. Lobstermen, a subpopulation of commercial fishermen, are a predominantly male population.[4] Women who harvest lobsters identify with the term regardless of gender specificity.[4,5] In the United States, most lobstermen are licensed at state, rather than federal, fisheries management offices to harvest within state-defined marine boundaries (inshore). A lesser proportion is licensed to harvest federal waters (Offshore).[6] Most inshore boats have a captain and a sternman or 2, while about 30% are operated by the captain, only.[6] The inshore boats make day trips, leaving, hauling a few hundred traps, and then returning to their mooring the same day.[7] The hauling is done with mechanical assistance, but when the trap gets pulled on board, manual material handling requires an average handling time of about thirty seconds per trap.[7]

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"Breaking the trap" consists of (1) hauling a trap out of the water with hydraulic-powered mechanical assistance, (2) manually pulling in a trap hanging from a trapline, and (3) placing the trap onto the washboard at the side of the boat. The traps may be set one per buoy or linked together in trawl strings of up to 20 traps, depending on the norms of the area.[7] The repetitive material handling exposes lobstermen to forceful exertions, often with awkward postures, corresponding to an observable profile of musculoskeletal disorders in the population.[4] Other exposures include noise, slips and falls, and stress. Conversely, the offshore boats remain at sea for several days and may haul considerably more traps. Inshore boats average about 31 feet in length, and offshore about 54 feet.[6] Within the lobster boat fleet, the onboard workspace variability and size have not been objectively studied. However, boat-building knowledge and traditions are maintained by local boat builders,[8] while safety policies may not have evolved in response to design and equipment development.[9]

Occupational exposures are specific to individual fisheries, as prior research has indicated.[10] Recent investigations of lobstermen's pains and injuries[1,4] were, in part, a response to a dearth of occupational health literature in commercial fishing.[11] A prior study of lobstermen showed an occupational injury incidence rate of 17.5/100 full-time equivalent (FTE), and an occupational fatality rate of 21/100,000 FTE.[1] Half of the injuries affecting routine work were sprains. These rates are higher than land-based industry rates measured by the Bureau of Labor Statistics.[12] Another study showed half of lobstermen experienced low back pain, requiring work alteration 6% of the time.[4] The variability of lobstering work practice behavior, like workplace dimensions, has not been objectively evaluated.

Participatory Ergonomics to Learn More About Lobstering

PE is a well-established methodology. Wilson's[13] definition of PE[14] is the "involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals." Lobstering is an industry featuring thousands of decentralized, independent, autonomous operators who engage in all aspects of their work through a "do-it-yourself" approach on nonstandardized boats, a natural setting for PE, but an environment that is typically remote and unfamiliar to land-based researchers.

The PE research methodology draws from a variety of field settings and intentions,[14] contributing to a generic "Participatory Action Research" (PAR) field that mixes scientific principles with action-oriented outcomes to meet a range of objectives.[15] Typically, preliminary analysis of the institutional or organizational site, found in organizational charts, key informant interviews, or other methods, is essential for PE research.[16,17] Howard's metabolism[2] raises the possibility of expanding the structural context of this PE research beyond the typical institutional setting.

Does the decentralized nature of the industry present an opportunity for structural development? From the field of PAR, knowledge about the effectiveness of community participation in identifying health issues and intervention planning helped shape a movement that manifested into a wide variety of community health structures and processes.[18] When, for example, Jones analyzed the persistence of health disparities in Native American populations, he found that, despite the effectiveness of participatory methods, underlying socioeconomic determinants of health were often too powerful to meet expectations of health improvement by the researcher and participating subjects.[18] In the context of Howard's metabolism,[2] it is incumbent on the researcher to focus on participatory research as an opportunity for structural development[19] in the fields of health research and practice and of lobster harvesting.

The PE method allows the participating lobsterman to define what is needed to reduce exposure to risk for pain and injury. By introducing a principled approach emphasizing industry-wide impact in the decision-making process for individual participants, we addressed the potential for this independence to become an obstacle to systematic intervention. The principles of the method, described below, also bridge multiple levels of translational research, while not fitting completely into one category.[11] In this way, PE in lobstering can inform intervention technique, organization, policy, and dissemination, and is essentially a learning process not limited to the participants.[20]

Research Questions and Guiding Methodological Principles for This Research

These case studies constructed a transformative research paradigm with an action-oriented, PE model for reducing occupational risk for pain and injury. The basic questions under investigation were:

1. How can risk for occupationally related pain and injury be reduced in the lobster harvesting industry?
2. What can be learned from a PE research model for intervention in lobstering?
3. What are key factors in determining effectiveness in reducing exposure to risk for musculoskeletal disorders?

Participatory methods vary[21–24] within different programs,[25] industry,[26] intent,[27] culture,[28] and worksite.[29] These 2 case studies were based on 4 principles[30] couched within 6 steps common to participatory research,[31–35] and in accordance with a utilitarian Scandinavian work environment model.[22,35]

Four Guiding Methodological Principles for This Research:

1. The primary subjects were lobstermen.[30] However, research participation included individuals in support of the industry, even if these individuals were not themselves research subjects if the active research benefitted from their input.
2. The meaning and form of participation reflected the culture and norms of the industry and needed to be compatible with the time and resource constraints of lobstering.
3. When developing ideas on ergonomic intervention participants must consider the potential for widespread industry acceptance.
4. The overall intervention must include strategies for diffusion of both technological and organizational interventions.

By observing the lobstermen as they evaluated how to improve their conditions, information was sought on factors that might influence their thoughts and actions. These data could inform policy or action aimed at reducing exposure to risk for musculoskeletal pain or acute injury.

Methods

Stepwise Process

Recruitment for the 2 case studies began by using a contact list of commercial lobster license holders from Maine and Massachusetts who had participated in a previous survey on injury and musculoskeletal disorders.[1,4] A convenience sample of captains was drawn from this list, and those lobstermen were contacted via telephone. Calls were made repeatedly until contact was made directly with the captain. The captains were informed about the research and asked to give appropriate consent for their vessel to be enrolled. Captains and sternmen consented individually to participate in this study. The results of 4 of those participating individuals, from 2 boat crews, are the focus of this manuscript.

The completed informed consent forms were filed with the UMass Lowell Institutional Review Board for Human Subjects (IRB No.:16-118-BUC-XPD). Lobstermen were compensated at 50 dollars per meeting with an additional 100 dollars incentive to complete all 8 meetings.

Meetings. The PE process consisted of a stepwise progression of 8 meetings between the researcher and participating lobstermen of each crew, respectively (Table 1), with study data being generated at each step. These steps occurred at a convenient location conducive to conversation, using displays and materials to enhance understanding between the 2 parties. The data collection methods were flexible to adapt to the subjects' environments and intentions and allowed the researcher to guide the research in accordance with the stated principles. The process was designed to take place over 8 to 16 weeks, but, if necessary, could have been extended any length of time to assure the process would continue. The first step of the research was an informal, preliminary discussion to inform participants about the research and obtain written consent. At this time, the researcher also obtained a preliminary understanding from the captain and sternmen of the potential type of problem and character of intervention to anticipate.

The second step of the process was the first formal meeting with the participating subjects. An ergonomics training specifically developed for this research was delivered in accordance with adult learning techniques such as demonstrations of biomechanics using common materials, direct participant involvement in captain–sternman role play, or mimes of manual material handling tasks. The training focused on the relationship between pain and work, the identification of risk factors for pain, the qualitative and quantitative aspects of a healthy fit between the work and the worker, the levels of intervention, the definition and characterization of their community, and the acknowledgment of stakeholders in the process of implementing an intervention.

The third step was hazard identification. Three methods for identifying hazards were systematically used: a Nordic Musculoskeletal Questionnaire[36] (NMQ) adopted slightly for lobstering, a Visual Analog Scale[37] (VAS) assessing strain associated with specific tasks, and an observational ergonomic job analysis[38] (EJA) was made of a routine fishing trip. The second crew was encouraged to use their cell phones to photograph and video the hazards as they saw them.[39,40] The NMQ and VAS were data collection sheets that were filled out by the participants. The EJA was completed by the researcher who was trained in observational ergonomic analysis. Semistructured interviews were conducted during the meetings to collect qualitative data on exposure and intervention. The semistructured interview started with a set of basic questions that gave structure to the interview. Depending on the participants' answers, the interview would generate a discussion or further, unprepared questions.

The fourth step was a set of meetings focused on intervention. Semistructured interviews were conducted in this step, as well. Researcher notes taken during this step were used during the evaluation and extraction steps, below.

A report on the EJA observations made in Step 3 was provided to the participants. It included photographs and videos of the entire sequence of activities and tasks performed by the subjects. The report was used to stimulate discussion for analysis and prioritization of problem to solving. The researcher guided the generation and prioritization of intervention ideas by helping the subjects to reduce the perception of risk into basic components, such as force, posture, or repetition.

Data collected during the first 4 steps included the subjects' evaluation of the training; NMQ surveys of the participants; subjective and objective observations, photographs and videos of the work; subjective VAS ranking of strain

Table 1. Steps of Participatory Ergonomic Research Process.

Step	Meeting	Focus	Data collected: Qualitative	Data collected: Quantitative or semiquantitative
1 – Recruitment	*	Study information	Informal discussion notes Informed consent	
2 – Introduction	1	Study intentions; background information; definitions; emphasis on engagement	PE orientation/training discussion notes Participant definition of community Participant evaluation questionnaire	
3 – Hazard Identification	2	Statistics on pain and injury in the industry; subjective experience	Meeting notes; Semistructured interview	Task-based VAS of discomfort, Modified NMQ, Photovoice
	3	Observation of operation	Notes of subjective hazard assessment	Subjective EJHA
	4	Prioritization	Meeting notes; semi-structured interview	
4 – Intervention implementation	5	Brainstorming, prioritizing, planning for intervention	Meeting notes; semi-structured interview	
	6	Implement intervention	Semistructured interview	Observations, measures of intervention effects;
	7	Review and evaluation of intervention effect	Semistructured interview of participants' subjective review and critique of intervention	
5 – Evaluation	8	Review and evaluation of research	Semistructured interview of research process and outcome evaluation	
6 – Analysis	*	Extract lessons	N/A	N/A

Abbreviations: NMQ, Nordic Musculoskeletal Questionnaire; EJHA, ergonomic job hazard assessment; VAS, Visual Analog Scale.

Table 2. Participating Subjects and Important Characteristics or Experiences.

Crew	A			B
Age	76	37	74	73
Sex	M	M	M	F
Title	Captain	Sternman	Captain/sternman	Captain/sternman
Years lobstering	43	1	36	64
Important characteristics or experience	Warehousing, and parcel service; Recent heart attack, muscle cramps affected sleep	Prior career in hotel management	Marine surveyor; recent heart attack; learned from wife's work techniques; observations in this study were made on his boat, but he also worked as sternman on her boat	Female in a male dominated industry; learned to adjust to physical capabilities; also a licensed captain and boat owner but worked on husband's boat for the purpose of observation in this study

associated with tasks; quantitative measurements of forces and distances in material handling; and the semi-structured interviews. Notes were taken by the researcher during each of the semi-structured interviews and of the researchers' subjective observations during each step.

The fifth and final step with participants was process and outcome evaluation. This step occurred with all the study participants in their respective crews, with the tragic exception of 1 participant's sudden death. The data were collected by semi-structured interviews of the subjects. For analysis, the interview data from each of the steps were reviewed by the researcher to identify themes and patterns from the interviews.

In the sixth step, extraction, the researcher conducted a content analysis of the data inclusive of both crews. Themes were organized from these data into descriptive content (ex. – personal experience or perceptions of injuries), structural content (ex. – reasons why high injury rates persisted) and contrasting information (ex – male vs. female perceptions of risk). These data collected in prior steps via EJA were also used to evaluate the process and outcome of the research, particularly to gain a perspective of potential versus actual implementation.

Results

Steps 1, 2—Recruitment and Introduction

Each crew was a pair of lobstermen from Massachusetts (Table 2): Crew A—2 male lobstermen from south of Boston, and Crew B—a husband/wife team from north of Boston. Their moorings were within popular medium-sized harbors with about 40 licensed boats, respectively.

Because crew A was interested in a community-based intervention, other individuals were organized to build influence within the political structure of their community. The captain of crew A garnered considerable respect in the community. Crew B recognized that their experience as a husband/wife team on the water was unusual and a determining factor shaping their ergonomic intervention ideas. Telling their story would encourage others to adopt some of their best practices through future work. Thus, the participants' decisions to pursue community-based interventions reflected their character and interest from the beginning, which is strongly in accordance with the third principle of the participatory methodology.

Step 3 – Identifying Hazards and Health Problems

The participants and researcher together found consensus on the nature of exposures, and how the exposures affected lobstermen (Table 3) by reviewing the data from the EJA[38] of the subject's routine fishing trip, a VAS[39] that ranked the subject's discomfort per task, and a modified NMQ[36] that counted the subject's episodes of pain and discomfort. Crew B also was encouraged to photograph and video the most important exposures to risk on their own.[39,40]

The VAS discomfort rating scale showed the highest average score was pulling in the trap, ie, "breaking" the trap onto the washboard (Table 4). The irregular task of breaking traps with tangled lines was described as requiring forceful exertions and awkward extreme postures. One subject added more tasks to the list that were specific to a singular high exposure to risk for pain at the beginning of the season, after returning from a winter off. These tasks would be considered "irregular" because the conditions are not routinely part of work throughout the year. He also added the task of taking lobsters out of the tank, not previously listed, with a rank between 6 and 7.

All subjects reported experiencing pain and discomfort, both work- and non-work related, in multiple locations within the last 7 days and last 3 months (NMQ). Subjects reported osteoarthritis (described as "'osteoarth-wrong-is' because there's nothing right about it") and muscle cramps as non-work-related pain or discomfort, but these conditions may have been work-related. Two subjects had experienced heart attacks within the previous 2 years.

The husband of Crew B observed that his wife's biomechanical capabilities had prompted her to adopt alternative material handling techniques and noted that a typical male lobsterman would not question the manual handling demands of their work. For example, she loaded bait into a truck by stacking and sliding 70-pound boxes without lifting. Thus, they felt that they had more insight into hazard identification than the ordinary crew because their career perceptions were not biased by machismo.

Step 4—Interventions

While many intervention ideas were generated, (see online Supplemental Table 1), after prioritization, 4 ideas were selected to be implemented:

1. A star block (Crew A).
2. A conveyor belt for the pier (Crew A).
3. An engineered change to mechanical assistance for pulling in traps from the water (Crew A).
4. The development of a series of videos highlighting good ergonomic practices already adopted by individual lobstermen (Crew B).

Ideas 2 and 4 showed that both crews expanded the focus of the research beyond their own personal exposure and into the community.

(1) *Star block (Crew A)*. The star block was produced and donated by a company in Maine for the purpose of evaluation. This suggested intervention had the possibility to mechanically reduce shoulder extension while "breaking" the trap. NMQ data from these participants, and data from prior investigations,[4] converted on shoulder pain as an important concern. A block supports a rope being pulled in by hydraulic motor. The star block had a sprocket-type wheel on the open-ended side rather than a smooth wheel (Figure 1) that mechanically separated the gangion line or bridle that connected the trap to the trapline, so that the trap didn't follow the trapline into the hauler. A regular block requires shoulder flexion for the lobsterman to manually remove the gangion or bridle at each trap. The subject understood that repetitive, forceful shoulder extension corresponding to the work element of removing the trap's bridle from the block was exposure to shoulder MSD. The star block vendor recommended that it be used for a couple of weeks so that the lobsterman could adapt his work habits. The star block was observed to perform as intended during the trial on the subject's boat. However, the subject's unfamiliarity with its use and the fact that he was hauling in relatively shallow water made the trapline sag horizontally and therefore perform inconsistently. The trial was abandoned when the subject felt pain in his back associated with the unintended use of the star block.

Table 3. Descriptive Ergonomic Analysis and Corresponding Intervention Ideas Proposed by Participating Research Subjects.

Work element	Crew	Body location	Risk factor	Intervention idea		Additional concerns
Squatting to reach bait (storage location under table)	A	Trunk, Shoulder	Severe forward flexion Elbow above shoulder height	Boxes of bait may be stacked; stacked boxes allow work at waist height	2-man lift onto table	Bait from fish market; type of bait may vary (lobsters won't eat same thing every day)
Manually handling traps (pull in, carry, drag, stack)	A	Trunk Trunk, Upper extremities	High force Awkward posture	Robotic arm to move and place traps	Install and use hoist at pier	Lifting/carrying techniques: close to hip; one hand bridle, one hand to side guiding without gripping; mechanical advantage from wave inertia
Manually handling traps (pull in, carry, drag, stack)	A, B	Trunk Upper extremities	Awkward posture Repetition	Robotic arm to move and place traps Another table (above) to allow bait work at waist level and stacked traps over the top of that (with consideration of robotic arm).	Install and use hoist at pier Stainless steel runners on tables	Lifting/carrying techniques: close to hip; one hand bridle, one hand to side guiding without gripping; mechanical advantage from wave inertia
		Upper extremities	Awkward posture Repetition High force		Stainless steel runners on tables Star block	Cost and opposition to hoist at pier; need for community organizing
		Lower extremity (knee)	Repetition High force Repetition			Knowing the current is important; cross-currents mess things up by creating more force when removing buoy from water
		Upper extremities	High force Repetition Awkward posture	Another table (above) to allow bait work at waist level and stacked traps over the top of that (with consideration of robotic arm). Move extended rail back toward stern	Star block	Knowing the current is important; Additional forces are created when the boat moves against crosscurrents when removing buoy from water Distance to bait a concern (speed)
		Lower extremity (knee)	Contact stress	Move extended rail back toward stern		
Mmh – bait	B	Low back	Forceful exertion	Slide rather than lift	Smaller packages – 70 lbs not 120–150 lbs; fewer traps – was 100 now 60	Boat space limitations
Taking out lobster	B	Low back	Awkward posture	Crank bottom, crate in tank		
Maintaining balance	B	Knees, feet	Forceful exertion	Catamaran	Seats in cabin	
Repairing traps (non-routine)	A	Shoulders	Awkward posture	Angle work surface toward work	Powered tools	Power supply
		Upper extremities	Awkward posture Forceful exertion			Irregular, nonroutine activity

Table 4. Average Visual Analog Scale (VAS) Score of 8 Most Common Lobstering Tasks.

VAS	Task
7.7	Pull in trap (higher if early in season)
6.7	Stack traps
4.2	Gaff
1.7	Remove trap contents
1.6	Rinse down
1.3	Gauge lobster
1.0	Band lobster
0.8	Rebait/reset

(2) *Conveyor belt*. At the pier of Crew A, there was no mechanical assistance available to move bait, lobster crates, or any other equipment, from the boat to their trucks. A typical crate full of lobsters weighs about 90 pounds. The lobstermen must manually drag the load across a float (40–150 ft), up a ramp (40 ft-long, at varying angles depending on tide), and lift it into their trucks. The idea of a conveyor belt was to intervene with mechanical assistance to move the load up the ramp section. The intervention was viewed as a benefit to others in the local lobster community. A community-based mechanism was needed to meet the cost of implementation. A strategy was developed to acquire $50,000 of funding through a state funding agency. The lobsterman had invested significant time and energy into organizing community support, including an appearance with the researcher in a panel discussion on current challenges for local lobstermen at the port's annual "Heritage Day". Unfortunately, this captain suffered a fatal heart attack before the intervention could be implemented. The sternman completed the evaluation step and the research with this crew was concluded. This did not affect Crew B.

(3). *Mechanical assistance for handling a trap*. Prior to his death, the captain had expressed a desire to fish for many more years but recognized his aging body had begun to show its limits. Inspired by such equipment seen on a larger trawler boat, he proposed engineering a robotic arm to lift the trap out of the water, place it on the boat's washboard, then place it on the stern after manual clearing and rebaiting. He had also expressed curiosity at how other lobstermen performed this task: "How do other lobstermen get traps to come to the rail the same way all the time?"

Initially, this appeared to be beyond the scope of the research. However, the possibility of utilizing student researchers to develop the idea was raised and the subject agreed to this approach. A team of mechanical engineering students at UMass Lowell produced an innovative design for mechanical assistance with block-related activities. The students' conception was to equip the block with an actuated, additional degree of freedom to adjust the height during hauling. This would allow the lobsterman to lower the block and reduce shoulder extension during the sequence of feeding the trapline by hand into the block. After that sequence, the block could be raised high enough to lift the trap in front of the lobsterman, who can then reach straight out to pull in the trap to waist height to prevent severe forward trunk flexion required to lift and pull the trap onto the washboard. The design has not been prototyped yet.

(4). *Video series on ergonomic ideas already in practice*. Consistent with the participatory principle to develop an intervention with the greater industry in mind, Crew B proposed to develop a series of videos on lobstermen's ergonomics. The participants felt that disseminating ideas of experienced lobstermen like themselves was the best way to advance the research and ergonomics in the industry. This perspective had been shared by Crew A, when the captain described a structural reality about the dissemination of ideas among lobstermen: "When lobstermen get together, they start complaining and talking about the latest issues that threaten them. They don't talk about equipment, how to make certain repairs, who in the community is reliable for service, etc." Both crews reflected a lack of a forum for ergonomics in their social interactions. It also revealed a tendency to reserve their highest respect for the successful experience of their peers.

Crew B collected video data on a peak exposure during their work process. The researcher videoed an interview of them discussing the exposure and the method they adopted to help reduce force demands during the task. The identified risk for injury was associated with the manual material handling necessary to untangle 2 different traplines that had been laying one over the other underwater until hauled up together. As the lobsterman would go on to describe in the video, this task has exposure to high risks for musculoskeletal disorders. Unknown and unpredictable forces acting in different directions must be controlled manually. Each trap can weigh 40 pounds or more, and a trapline may hold up to ten traps or more. When 2 traplines are twisted, the entangled line gets stuck in the block and may cause a violent reaction if the hauler were to continue. If the lines were cut with this strain on the line, it could also result in a violent reaction. This footage was edited to produce an illustration of what the problem was, and how they solved it.[41] The researcher committed to developing a series of similarly structured videos of other lobstermen's ergonomics ideas in the industry.

Step 5—Evaluation

The participants' evaluation of the introductory training and orientation to PE was generally positive. The information on pain and injuries, how they are caused, and what can be done about it, was interesting to them. They commented that the researcher was knowledgeable, and the presentation was engaging. A recommendation for improvement suggested the training be delivered to new sternmen through an apprentice program. However, no such program existed in Massachusetts. One critical comment was that the researcher

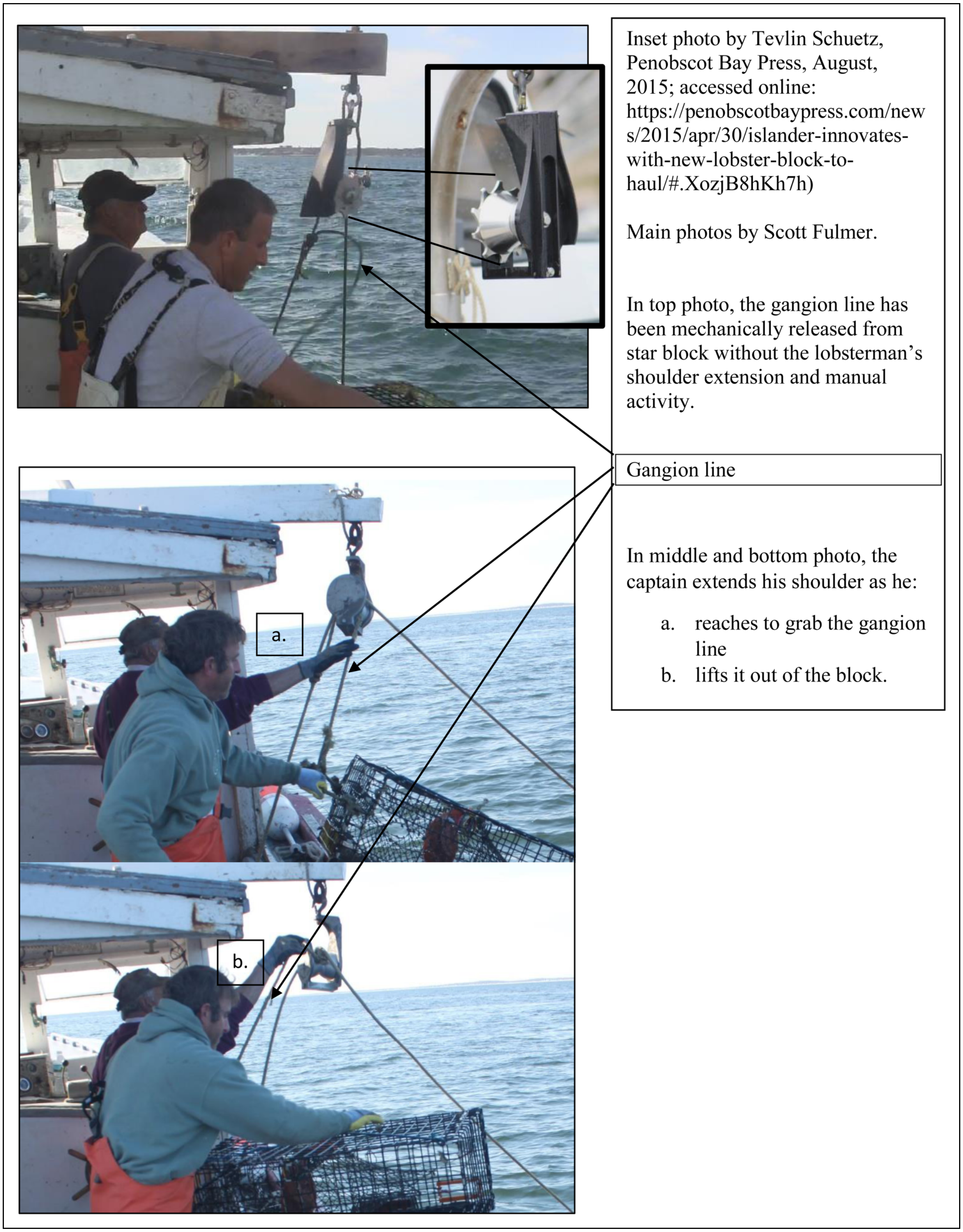

Figure 1. Star block in use (Inset: close up) and regular block in use for comparison.

needed to commit to long-term research with 1 boat because the seasonality of the work puts a demand on the subjects to work, not meet-up or talk. The attention to MSDs was appreciated, in contrast to the usual and expected disregard typically experienced by lobstermen.

The evaluation of the overall research steps showed participants were aware that the research was a novelty in the industry. Nevertheless, they were optimistic that it would be beneficial to the industry. Crew B were pleased with the video, which was the outcome of the research. The Crew A sternman was impressed with participatory design, liked the overall experience, and encouraged further research. These evaluations suggested that the participants were willing, acting in accordance with, and under the belief that the purpose of the research was for a greater good.

Step 6—Extraction

Crew B's use of photos and videos to identify hazards helped the crew to focus on the development of a series of videos on lobstering ergonomics as an intervention idea, consistent with the third and fourth principles for PE research stated a priori. After the initial video was developed, the evaluation of the problem identification and intervention steps affirmed that the lack of a forum for ergonomics in lobstering was a critical impediment to improving the industry.

One lesson extracted from the incomplete process of installing the conveyor belt was a policy implication for community development (the extracted lessons from the participatory steps are noted in online Supplemental Table 2). With the loss of the captain's political leadership upon his death, community members previously unresponsive to the captain's organizing expressed some regret at his wake and promised to be more open to the concerns of the lobstermen. Ultimately, however, a solicited proposal for a $20,000 installation lost a 10 to 7 vote of approval by the associated lobstermen maintaining the pier. After the vote, interviews with lobstermen showed the difference in the vote was due to "part-timers" who all voted against it. It was understood by the "full timers" that the "part-timers" were not experiencing the same cumulative exposure to physical fatigue. The deliberate focus on a community-based ergonomic intervention depended on the leadership of the participant and the fidelity of the community to the desired outcome.

Discussion

This report describes findings from PE research in the lobstering industry. By constructing a transformative paradigm for research with an action-oriented, PE model for reducing occupational risk for pain and injury within the lobstering community, this research responded to a prior study that identified high rates of injuries and prevalence of pain.[1,11]

In response to the first research question (How can risk for occupationally related pain and injury be reduced in the lobster harvesting industry?) intervention ideas were developed to reduce exposure to forceful exertion on the lobster pier, reduce forceful exertion and awkward back and shoulder postures during the work element of "breaking traps", and to create a forum to disseminate useful ergonomic ideas to other lobstermen. The research also generated practical information on factors for effective implementation that centered on organizing and community action, either through personal relationships or social media. The study findings are useful both for the immediate implementation of ergonomic interventions and for informing future health and safety research in this industry.

The results suggested that a forum for communicating intervention ideas is critical to raising awareness across the industry. This finding is reflective of a fundamental lack of communication about the work environment and methods of lobstermen. The researcher played a role in developing these thoughts and in pursuing intervention ideas that may not have happened, otherwise. However, the video about lobstermen's ergonomic ideas was evidence to show that ergonomic interventions are part of the natural process of improvement for lobstermen and can be communicated as such, given resources such as the current funded study. The use of students in developing the robotic arm concept was beyond the resources available to the typical lobsterman.

Effective key factors to reduce exposure to risk for MSD included support from other lobstermen, as in the case of the conveyor belt; time for adopting a new method or equipment, as was the case with the rejection of the star block after only one brief usage of it; and the time and resources required to design and test an engineering change, as was observed with the development of the robotic arm concept.

An important context for the intervention ideas was the character and experience of the subjects and how their biases and investment in the research affected the research outcomes. Notably, 3 of the 4 lobstermen were over 70 years old, with a combined total of 143 years of lobstering experience. They had also participated in prior sociological research on commercial fishing so had demonstrated a concern for the greater community. Both male captains had had cardiac health issues within the 2 years prior to their participation, so health and job strain were major concerns. Experience and investment in the research, then, were clear and consistent across these 3 crew members. It was not the intention of the researchers to find statistically generalizable results. Rather, participants were guided to consider widespread impact from their perspective and their years of experience gave them some confidence in their suggested interventions.

The captain from Crew A viewed himself as outside the norms of practice in the lobster fishery. The norm for lobstermen, he felt, was to operate independently without consciously addressing ergonomics or community participation. He was also vocal about his concern for the community, that it had lost its working-class character, that getting lobstermen to organize was "like herding cats."

All participants made it clear that ergonomics was less of a priority to them than productive lobstering. However, unlike prior observations in construction,[42] this does not mean that they placed a low priority on ergonomics. They viewed their labor in the context of understanding how to successfully find and catch the lobsters. This view could be misinterpreted as indifference to ergonomics, but by applying Howard's[2] view of lobstering as metabolism, it revealed that their cultural norms, in practice, lacked the possibility of any perspective more conducive to ergonomics.

Statements by the captain of Crew A unintentionally revealed this impossibility was due to the relative weight given to the political economy of fishing. Fishermen's internal solidarity against issues that threaten them mattered more in lobstermen's interpersonal relationships than did sharing knowledge about the means of production with each other.

Still, they recognized that the absence of information exchange was a barrier eclipsing the development of ergonomic ideas. This may help explain why high rates of injury continue in the industry.[1] In this context, injuries exhibit a structural causality.[19] Consistent with Crew A's complaint that lobstermen don't communicate about their work, the intervention idea that Crew B agreed to pursue (the video of their work method that reduced exposure to biomechanical risk) was intended to improve the possibility of mobilizing ergonomic ideas and address this structural issue. For the researcher, it was seen in accordance with Seymour's[19] call for structural development.

Hall-Arber et al's[43] study of New England fishing communities concluded that to be effective, political changes should not be implemented through a regulated standard but should build on existing community structures that form the basis for economic activity in a specific harbor area.[43] Research is important in recognizing how structural variability across different communities can affect communication about prevention and risk for musculoskeletal disorders.

The captain of Crew A viewed the research as a means to create something for the industry that was needed but effectively not available. In his opinion, research was a means to experiment with the things that lobstermen couldn't afford. However, the effectiveness of the students' ideas, remains an open question, even if the cost of developing them amounted to nothing for the participant.

The limits of what the participants thought they could afford affected their research focus. While recognition of an industry-wide dimension is inherent to the participatory process, the observed perception of research as a means to create more affordable intervention suggests that ergonomic change would be best introduced as parameters or guidelines for specific, individual adaptation, whether on a boat or in the community.

Strengths and Limitations

While this study was not designed to analyze population-level data, subjects contributed experienced knowledge on probable population tendencies. Some confidence in these findings is supported by the convergence of multiple methods of data collection and by agreement with prior findings.

The principles of the research design may have influenced the findings. Nevertheless, the participatory design intentionally opened the possibility to identify unseen or qualitative factors that might affect intervention. Despite the possibility of creating new practices and equipment through the research, the participants drove the research to consider ergonomics more broadly at the community level.

Conclusion

Four intervention ideas to reduce risk exposure for biomechanical strain associated with manual material handling were introduced and evaluated through a PE method. While these ideas need further development, they reveal practical insights on steps that lobstermen, and people associated with the industry, can take to begin reducing risk for biomechanical strain. Their peers' experience with equipment, technique, and ergonomic intervention was highly valued, with variation in community structure being expected but understudied. These outcomes built on existing ergonomic knowledge and sought to increase lobstermen's awareness. Occupational research, practice, and policy may be necessary to make conditions conducive for converting this awareness into action.

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Supplemental Material

Supplemental material for this article is available online.

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