Ergonomic Risk Factors for Low Back Pain in North Carolina Crab Pot and Gill Net Commercial Fishermen

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Background *The objective of this research was to determine the association between LBP that limited or interrupted fishing work and ergonomic low back stress measured by (1) self-reported task and (2) two ergonomic assessment methods of low back stress.*

Methods *Eligible participants were from a cohort of North Carolina commercial fishermen followed for LBP in regular clinic visits from 1999 to 2001 (n = 177). Work history, including crab pot and gill net fishing task frequency, was evaluated in a telephone questionnaire (n = 105). Ergonomic exposures were measured in previous study of 25 fishermen using two methods. The occurrence rate of LBP that limited or interrupted fishing work since last visit (severe LBP) was evaluated in a generalized Poisson regression model.*

Results *Predictors of severe LBP included fishing with crew members and a previous history of severe LBP. Among crab pot and gill net fishermen (n = 89), running pullers or net reels, sorting catch, and unloading catch were associated with an increased rate of LBP. Percent of time in forces >20 lb while in non-neutral trunk posture, spine compression >3,400 N, and National Institute of Occupational Safety and Health lifting indices >3.0 were associated with LBP.*

Conclusions *Tasks characterized by higher (unloading boat and sorting catch) and lower (running puller or net reel) ergonomic low back stress were associated with the occurrence of severe LBP. History of LBP, addition of crew members, and self-selection out of tasks were likely important contributors to the patterns of low back stress and outcomes we observed. Based on the results of this study, a participatory ergonomic intervention study is currently being conducted to develop tools and equipment to decrease low back stress in commercial crab pot fishing.* Am. J. Ind. Med. 2009. *© 2009 Wiley-Liss, Inc.*

KEY WORDS: epidemiology; musculoskeletal disorders; work exposure; PATH; CABS

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INTRODUCTION

Back pain is a common occupational problem in commercial fishermen. In a cross-sectional study of Swedish deep-sea fishermen, half of fishermen experienced low back symptoms during the last 12 months [Torner et al., 1988a]. Low back symptoms were the most common cause of work impairment among a cohort of North Carolina commercial fishermen [Lipscomb et al., 2004]. Risk factors for the prevalence of low back symptoms include age, length of time in the occupation, type of fishing and gear, job title, and fishing part-time, or working more than one job [Torner et al., 1988a; Lipscomb et al., 2004]. However, the importance of these factors from a prevention standpoint is limited by the degree to which they are modifiable. Little is known regarding the relationship of LBP with specific fishing tasks, their frequency, or their duration. It has been previously documented that fishermen perform strenuous tasks [Torner et al., 1988a; Lipscomb et al., 2004; McDonald et al., 2004], and ergonomic studies have evaluated biomechanical low back stress for fishing tasks [Torner et al., 1988b; Fulmer and Buchholz, 2002; Mirka et al., 2005; Kucera et al., 2008]. However, no study has evaluated specific tasks and ergonomic measures as risk factors for low back pain in a population of fishermen.

Previous studies have described characteristics of fishing work such as static, awkward working postures, shoveling and lifting tasks, which produce strain to the low back area [Torner et al., 1988a; Lipscomb et al., 2004; McDonald et al., 2004]. Ergonomic analyses of commercial fishing crews revealed that work tasks were repetitive and cyclic with high-intensity lifts during loading and unloading activities [Torner et al., 1988b; Fulmer and Buchholz, 2002; Mirka et al., 2005; Kucera et al., 2008]. More specifically, low back stress varied by the type of fishing performed, size of the crew, job, and task performed [Kucera et al., 2008]. While certain job characteristics may produce low back stress, their association with low back pain in fishermen is undetermined.

The objective of this research was to determine the association between low back stress and low back pain that limited or interrupted fishing work. Low back stress was measured by (1) self-reported task and (2) the percent of time exposed to low back stress (measured with two ergonomic assessment methods). A secondary objective was to examine the influence of other covariates such as previous history of severe LBP, age, and years fishing experience. Our study population was a group of southeastern US commercial fishermen who fished with crab pots and gill nets in small-scale, independent operations on coastal or inland waters.

MATERIALS AND METHODS

Study Population

Participants in this study were members of a cohort of commercial fishermen originally assembled during the period of April 1999 to May 2000 for the purpose of studying exposure to a toxic marine micro-organism [Moe et al., 2001]. This population included licensed commercial fishermen 18–65 years of age who fished on inland rivers and sounds or on the ocean for at least 20 hr per week for at least 6 months of the year. Individuals completed self-administered questionnaires at baseline and at 6-month intervals during medical clinic visits for a period of up to 2 years. Information was gathered on the presence of musculoskeletal pain, traumatic injuries, and fishing activities and other exposures. In addition to regular visits, fishermen were encouraged to come in for ‘‘trigger’’ visits defined by conditions relating to exposure to toxic micro-organisms (e.g., skin lesions, memory loss, cognitive impairment) or if they were exposed to diseased fish [Moe et al., 2001]. Fishermen were also interviewed every 1–2 weeks by phone from August 1999 to May 2002 about work-related injuries, fishing activities, and other exposures of interest. Injury data from clinic visits and follow-up of the cohort have previously been reported [Lipscomb et al., 2004; Marshall et al., 2004].

A Supplemental Questionnaire was administered by telephone in April of 2004 to retrospectively assess more details on fishing and non-fishing work exposures and whether they performed specific fishing tasks. Of 177 fishermen available for interview, we were unable to reach 60 participants (contact number not available, n = 27, and unable to reach, n = 33); of those we did reach, 106/117 agreed to participate. *Note*: we use the term fisherman because that is how the participants, men and women, referred to themselves and to others. The University of North Carolina at Chapel Hill School of Public Health Institutional Review Board approved all study procedures and all subjects provided written informed consent prior to participation.

Low Back Pain

A revised version of the Nordic Musculoskeletal Questionnaire [Kuorinka et al., 1987] was administered in all clinic exams to determine the presence and severity of LBP at baseline and subsequent follow-up visits. Reliability of the instrument ranges from 77% to 100% and validity, compared to clinical history, ranges from 80% to 100%. Information collected included 12-month prevalence of low back pain at baseline and occurrence of LBP since last clinic visit. For both baseline and follow-up clinic visits, participants were asked if this low back pain limited work (reduced work level or tasks) or interfered with work (unable to work for a day or more) and, if so, how long they were unable to work. For this study, severe LBP was defined as any reported LBP that limited or interfered with normal fishing work activity. We could not determine whether reports of LBP at follow-up were new or recurrent, therefore we consider all occurrences of LBP in this study.

Fishing Exposure

During the follow-up clinic visits fishermen reported the fishing methods (e.g., pots, gill nets, trawl, dredge) and type of catch (crab, finfish, shrimp, clam, oyster, or other) since last visit. In weekly (April–October) and biweekly (November–March) telephone interviews, the fishermen reported the type of catch, number of days spent on and off the water, and estimated the number of hours they spent on the water for the most recent day fishing. Detailed exposure information was gathered in the supplemental questionnaire for crab pot and gill net fishermen and included the frequency respondents performed specific fishing tasks (e.g., driving the boat, pulling in gear, unloading boat). A Likert rating scale (1–5) quantified the frequency of task performance: never, less than half the time but more than never, half the time, more than half the time but less than always, or every time/everyday. This scale was dichotomized for analysis as follows: if fishermen performed a particular task during the study period on average "more than half the time" or "always," then they were considered exposed to that self-reported task.

Ergonomic Exposure Assessment

In a previous study, ergonomic exposure to low back stress was measured in a purposive sample of 25 commercial crab pot and gill net fishermen using two ergonomic assessment methods appropriate for non-routine work [Kucera et al., 2008]. Researchers observed and video taped fishing work, both on and off the water, for a full day. Video tapes were coded for each fisherman using two different methods.

The first method, a work sampling based method, Posture, Activity, Tools, and Handling (PATH) [Buchholz et al., 1996], linked work tasks and activities with posture codes to estimate the percent of time workers spent in various situations stressful to the low back. Cut points were established from previous occupational studies. Non-neutral trunk postures [Punnett et al., 1991; Burdorf and Sorock, 1997], lifting 44.5 N (4.5 kg) at least once per minute [Punnett et al., 1991], and material handling tasks [Riihimaki, 1991; Burdorf and Sorock, 1997] have been identified as risk factors for low back pain. The percent of time fishermen were observed in low back stress was quantified for three PATH measures: percent of time in non-neutral trunk postures (trunk flexion $>20^\circ$, lateral bend and twist $>20^\circ$), percent of time handling loads or exerting force >20 lb (9 kg), and percent of time performing manual materials handling tasks (defined as lifting, lowering, carrying, holding, and pushing or pulling boxes, crates, baskets, etc.). The combination of force >20 lb in non-neutral trunk postures was examined to capture the multi-dimensionality of these two measures.

The second method, Continuous Assessment of Back Stress methodology (CABS) [Mirka et al., 2000], utilized three well-established ergonomic assessment methods to evaluate biomechanical stress of occupational activities: the revised National Institute of Occupational Safety and Health Lifting Equation (NIOSHLE) [Waters et al., 1993], the Ohio State University Lumbar Motion Monitor™ (LMM) [Marras et al., 1993], and the University of Michigan Three-Dimensional Static Strength Prediction Program™ (3DSSPP) [Chaffin et al., 1987; Chaffin and Erig, 1991]. Low back compression from 3DSSPP, lifting index from NIOSHLE, and the probability of high-risk group membership from LMM were measured for defined fishing tasks (e.g., driving the boat, pulling in gear) and combined with the estimated time and frequency fishermen were exposed to these tasks. These values were combined to form time–weighted distributions of low back stress.

Compression values >3,400 N have been associated with an increased risk for low back pain among workers [Lavender et al., 1999]. Lifting indices >1.0 have been associated with low back pain, while indices over 3.0 are reported as a potential problem for most workers [Waters et al., 1993, 1999; Lavender et al., 1999]. The percent of time fishermen were exposed to low back stress for these two measures were defined as follows: the percentage of time >3,400 N of spine compression, the percentage of time lifting index >1.0, and the percentage of time lifting index >3.0. Probability of high-risk group membership of 35% or greater has been identified as a problem for industrial workers [Marras et al., 1995]. Because the majority of fishing tasks in this study had >35% probability of high-risk group membership [Kucera et al., 2008], we evaluated a higher cut point of >70% probability of high-risk group membership. This variable quantified the percentage of time fishermen were engaged in fishing tasks in the upper 30% probability of high risk.

Exposure Assignment

At each follow-up period, exposure to low back stress was assigned to participants according to whether they fished with crab pots or gill nets (Table I). If fishermen fished with both methods during the period, they were assigned the fishing task and the higher ergonomic mean by type (crab pot or gill net). If they performed neither crab pot nor gill net fishing during the interval they were assigned a zero.

Data Analysis

Descriptive statistics were calculated by baseline demographic and work history characteristics as well as by fishing types at follow-up and self-reported job tasks from the supplemental questionnaire.

TABLE I. Fishing Task and Ergonomic Exposure Assignment by Fishing Type Performed During Follow-Up Interval for North Carolina Commercial Fishermen, 1999–2001

Fishing type performed during follow-up interval	Crab pot	Gill net	Fishing task assignment	PATH or CABS assignment
Crab pot only	Yes	No	Crab pot task	Crab pot value
Gill net only	No	Yes	Gill net task	Gill net value
Crab pot and gill net	Yes	Yes	Crab pot or gill net task	Larger value of crab pot or gill net
Neither	No	No	0	0
Did not respond to task questions	—	—	Excluded	Excluded

The occurrence rate of severe LBP was modeled using generalized Poisson regression [Rothman and Greenland, 1988] with log person-days at risk included as an offset term. Days at risk were calculated from days between clinic visits. Generalized estimating equations (GEE) [Liang and Zeger, 1986; Zeger and Liang, 1986] were used to account for the statistical dependence between multiple clinic visits and multiple severe LBP occurrences per fisherman. Outcome-covariate rate ratios (RR) and 95% confidence intervals (95% CI) were computed from the model and stratified by previous history of severe LBP. Confidence limit ratios (CLR, calculated as the upper confidence limit divided by the lower confidence limit) were produced to quantify precision for all estimates [Poole, 2001]. Non-overlap of stratum-specific confidence intervals indicated heterogeneity by previous severe LBP. Baseline covariates of interest were: gender, age, smoking history, fishing full time (at least 32 hr/week) or year round (at least 9 months of the year). Follow-up covariates included performing more than one type of fishing during the follow-up interval, fishing type and gear, and average hours per day on the water. Variables of interest from the supplemental questionnaire included years of fishing experience and work exposures during the study such as fishing with crew versus alone and working a non-fishing job during follow-up that required any of the following: frequent bending or twisting at the waist; work in awkward postures; frequent lifting (>3 lifts per minute); and lifting >50 or >25 lb.

For crab pot and gill net fishermen who answered the supplemental questionnaire, we modeled the rate of severe LBP by low back stress exposure measured with self-reported fishing task and PATH and CABS methods. PATH and CABS means were modeled with a multi-level mixed linear model accounting for the variability between and within fishing type, crew size within fishing type, and job type within crew size within fishing type [Kucera et al., 2008]. These means were included in Poisson regression models as continuous variables. The exponentiated parameters represent the change in the rate of severe LBP per 1 unit change in mean percent time exposed to low back stress measures. For example, the increase in the rate of severe LBP going from a peak of 29% of time to 30% of time in non-neutral trunk posture.

RESULTS

Descriptive Statistics

The majority of fishermen who answered the supplemental telephone questionnaire ($n = 105$) were male and between the ages of 30 and 59 (Table II). All except one were White, non-Hispanic. Most fished at least 32 hr per week for at least 9 months of the year and owned their own boat. Almost half worked another job not related to fishing. At baseline, 61% reported experiencing any LBP in the last 12 months and 24% experienced LBP that limited or interrupted their work in the past 12 months.

The 105 fishermen accumulated 58,143 person-days of follow-up during the study. Crab pot and gill net were the most common type of catch and fishing method reported (Table II). Over 40% reported spending on average 4–6 hr on the water their most recent day of fishing. Over follow-up, 61% (64/105) of fishermen reported 132 occurrences of any LBP since the last visit and 26% (27/105) of fishermen reported 40 occurrences of severe LBP. Sixty-eight percent of severe LBP occurrences (27/40) interrupted working activity for at least a day: 52% (14/27) interrupted work 1–7 days, 33% (9/27) 8–30 days, and 15% (4/27) over 30 days. When asked if LBP had ever caused them to change the way they fish, 37% said it had.

Participants began fishing at a young age (Table II). Over half had 20 or more years of experience as a commercial fisherman and most reported being a captain for most of their career. During the study period, the majority of fishermen worked with crew members (68%) and fished with others on a boat they owned (61%). Participants who worked a second non-fishing-related job during the study reported some form of low back stress in that job. Most were required to twist or bend frequently at the waist or lift >25 lb; fewer worked in awkward postures, lifted, repetitively, or lifted >50 lb (Table II).

TABLE II. Baseline Demographic and Follow-Up Information for North Carolina Commercial Fishermen Who Participated in a Supplementary Questionnaire (n = 105), 1999–2001

	n	%
Age		
18–21	3	2.9%
22–29	8	7.6%
30–39	19	18.1%
40–49	36	34.3%
50–59	28	26.7%
60–69	11	10.5%
Mean (SD), range	46.2 (11.1)	19–65
Gender		
Male	87	82.9%
Female	18	17.1%
Smoking history		
Current	39	37.1%
Past	29	27.6%
Never	37	35.2%
Baseline work exposures		
Own a boat	102	97.1%
Work regularly on someone else's boat	20	19.0%
Fish full time (32 or more hours per week)	84	80.0%
Fish year round (9 or more months of the year)	62	59.0%
Since last visit did you fish for. . .?		
Crab	82	78.1%
With crab pot gear	74	70.5%
Finfish	78	74.3%
With gill net gear	69	65.7%
Shrimp	43	41.0%
Oyster	19	18.1%
Clam	23	21.9%
Other types	26	24.8%
Average hours on the water per day during interview period		
Up to 4 hr	35	34.0%
Over 4–6 hr	42	40.8%
Over 6–8 hr	17	16.5%
Over 8–10 hr	4	3.9%
Over 10	5	4.9%
Missing	2	—
Mean (SD), range	4.9 (2.2)	1.3–11.6
Number of clinic visits per person		
At least 1	105	100%
At least 2	103	98.1%
At least 3	86	81.9%
At least 4–6	43	41.0%
Mean (SD) days between follow-up visit, range	162 (72)	38–736
Years as commercial fisherman		
0–9 years	6	5.7%
10–19 years	21	20.0%
20–29 years	32	30.5%
30–39 years	30	28.6%
40+ years	16	15.2%
Mean (SD), range	26.6 (11.5)	3–54
Age began fishing		
Mean (SD), range	19 (12.1)	5–54
Self-identified job title most often held. . .		
Captain	80	76.2%
Mate	18	17.1%
Co-captain	7	6.7%
When first starting to fish, did you fish. . .?		
Alone only	23	21.9%
With crew only	50	47.6%
Alone and with crew	32	30.5%
Work a non-fishing job during the study?		
Yes	47	44.8%
Did that job require you to. . .?		
Twist or bend frequently	28	59.6%
Work in awkward postures	16	34.0%
Lift repetitively (>3 lifts/min)	10	9.5%
Lift >25 lb	28	59.6%
Lift >50 lb	16	34.0%
Total	105	100%

General Risk Factors for the Occurrence of Severe LBP

The overall crude rate of severe LBP was 0.69 per 1,000 person-days (95% CI 0.47, 0.90) or 0.25 per person-year. Compared to fishermen 40 years of age and older, fishermen 18–29 experienced an increased rate of severe low back pain and fishermen 30–39 experienced a decrease in rate. Current smoking, fishing on someone else's boat, fishing types other than crab or finfish, and fishing full-time were associated with severe LBP (Table III). Fishermen who averaged the fewest and the most hours on the water had higher rate of severe LBP compared to fishermen averaging 0–6 hr on the water. Fishing year round and performing more than one type of fishing during the follow-up interval were not associated with severe LBP.

The occurrence rate of severe LBP decreased as years of fishing experience increased (Table III). Participants who fished during the study with others experienced an increased rate of severe LBP compared to those who fished alone. Workers with non-fishing-related jobs during the study were at decreased rate of severe LBP regardless of whether that job required frequent lifting, twisting, or bending frequently, awkward postures or lifting >25 or >50 lb.

Having a history of severe LBP was strongly associated with subsequent occurrence at follow-up (Table III). Among

TABLE III. Unadjusted Rate Ratios and 95% Confidence Intervals* of Low Back Pain Occurrences That Interrupted or Limited Work for North Carolina Commercial Fishermen (n = 105, Visits = 358), 1999–2001

	Severe LBP occurrences	Days at risk	RR* (95% CI)	CLR
Age				
18–29	10	5,081	2.4 (1.0, 5.8)	6.1
30–39	4	10,073	0.6 (0.2, 1.6)	7.6
40+	26	41,989	1.0	
Current smoking	20	21,346	1.8 (0.8, 3.7)	4.6
Not currently smoking	20	36,797	1.0	
Work on someone else's boat	9	10,162	1.5 (0.6, 3.5)	5.8
Work on own boat	31	47,981	1.0	
Other fishing types	12	25,690	0.6 (0.3, 1.1)	3.7
Crab or finfish	28	32,453	1.0	
Fishing full time (≥32 hr/week)	34	45,995	1.5 (0.6, 4.0)	6.7
Fishing less than full time	6	12,148	1.0	
Average hours on the water/day[a]				
0–6	32	42,921	1.0	
>6–9	4	10,861	0.4 (0.1, 1.5)	15.0
>9	4	3,202	1.8 (0.7, 4.4)	6.3
Years fishing experience				
0–9	5	3,157	2.5 (0.9, 6.9)	7.7
10–19	9	11,916	1.2 (0.5, 2.9)	5.8
Over 20	26	43,070	1.0	
Fished with crew 1999–2001	32	38,722	2.4 (0.9, 6.2)	6.9
Fished alone 1999–2001	8	19,421	1.0	
Non-commercial fishing job				
No	26	32,691	1.0	
Yes	3	6,365	0.6 (0.2, 2.6)	13.0
Yes with low back stress[b]	11	19,087	0.7 (0.3, 1.6)	5.3
History of severe LBP	27	15,302	6.1 (3.1, 12.1)	4.0
No history of severe LBP	13	42,841	1.0	

CLR, confidence limit ratio, upper confidence limit divided by the lower confidence limit [Poole, 2001].
*Poisson regression estimates are adjusted for multiple visits per subject with GEE.
[a]Average hours on the water, n = 103, visits = 352.
[b]Low back stress defined as the presence of one of the following: twist or bend frequently, work in awkward postures, lift repetitively, lift >25 or >50 lb.

fishermen with a previous history of severe LBP, smoking, working a non-commercial fishing-related job, and fishing full time were associated with an increased occurrence rate. Among fishermen without a previous history of LBP, increased occurrence rates were observed for fin fishing (specifically gill nets) and performing more than one type fishing.

Low Back Stress Measures as Risk Factors

For those who fished with crab pots and gill nets (n = 89), the majority fished alone (crab pots 70% and gill nets 64%). Fishermen reported performing an average of 8.7 (SE 3.7) fishing tasks over half the time (range 1–14). In general, over 90% of fishermen reported loading bait and/or supplies, pulling in, emptying, and setting gear, and cleaning the boat more than half the time (Table IV). Few regularly used a dolly or lift to load and unload their boats. A third operated pullers and net reels. The majority of crab pot fishermen reported baiting pots (83%) and the majority of gill net fishermen iced down catch (84%). Thirty-eight percent of crab pot fishermen helped sort their catch at the fish house or point of sale.

Analysis of self-reported tasks with these 89 crab pot and gill net fishermen (313 visits) indicated that running the puller or net reel, sorting catch on the boat, and unloading catch or supplies with or without mechanical assistance more than half the time were each independently associated with an increased occurrence rate of severe LBP compared to those who performed those tasks half the time or less

TABLE IV. All frequencies represent the percentage of fishermen who reported performing that task over half the time

	Among crab pot, n = 71 (%)	Among gill net, n = 55 (%)	Total, n = 89 (%)
Drive boat	87	82	89
Loading bait or supplies			
Without mechanical assistance	93	98	96
With mechanical assistance (e.g., dolly or lift)	15	5	16
Pull in gear (hook/pull in pot or pull in net)	90	95	94
Run puller or net reel	37	20	33
Empty gear (shake crab pot or pick fish from net)	83	96	93
Bait crab pot	83	—	—
Set gear (toss/push pot or run out net or toss net overboard)	86	85	90
Sort catch on the boat	41	64	63
Ice down catch	—	84	—
Unload catch and/or supplies			
Without mechanical assistance	87	91	89
With mechanical assistance (e.g., dolly or lift)	14	9	15
Sort catch at the fish house	38	—	—
Clean boat	86	91	92
Perform routine maintenance on boat or gear	77	84	81

Represent all frequencies the percentage of fishermen who reported performing that task over half the time.

(Table V). Driving the boat, loading bait and supplies with or without mechanical assistance, pulling, emptying or setting gear, cleaning the boat, and maintenance work more than half the time were not associated with severe LBP.

Little evidence for dose–response was observed for the combined number of tasks performed (RR = 1.1, 95% CI 0.9, 1.2). Stratifying tasks by potential exposure to low back stress revealed no difference between static tasks and

TABLE V. Crab Pot and Gill Net Fishermen: Unadjusted Rate Ratios and 95% Confidence Intervals* for the Occurrence of LBP That Interrupted or Limited Work for Self-Reported Fishing Task Frequency (n = 89, 313 Visits)

	Severe LBP occurrences	Days at risk	RR* (95% CI)	CLR
Drive boat	29	38,945	1.2 (0.4, 3.4)	7.9
Loading bait or supplies				
Without mechanical assistance	30	42,424	0.9 (0.3, 2.9)	9.6
With mechanical assistance (e.g., dolly or lift)	6	5,959	1.3 (0.4, 4.0)	9.5
Pull in gear (hook/pull in pot or pull in net)	28	40,837	0.9 (0.3, 2.3)	6.9
Run pot puller or net reel	19	14,719	2.5 (1.2, 5.5)	4.7
Empty gear (shake crab pot or pick fish from net)	29	41,061	0.8 (0.3, 2.3)	7.7
Bait crab pot (crab pot only)	26	33,621	1.1 (0.5, 2.4)	4.6
Set gear (toss/push pot or run out net or toss net overboard)	29	39,732	1.0 (0.4, 2.8)	7.4
Sort catch on the boat	23	25,651	1.9 (0.8, 4.3)	5.4
Ice down catch (gill net only)	17	26,035	1.2 (0.6, 2.7)	4.7
Unload catch and/or supplies				
Without mechanical assistance	30	38,987	1.5 (0.5, 4.6)	10.1
With mechanical assistance (e.g., dolly or lift)	9	5,799	2.5 (1.1, 5.6)	5.1
Sort catch at the fish house (crab pot only)	13	15,413	1.1 (0.5, 2.7)	5.8
Clean boat	29	40,398	1.0 (0.4, 2.8)	7.9
Perform routine maintenance on boat or gear	28	36,047	1.3 (0.5, 3.3)	6.6

CLR, confidence limit ratio, upper confidence limit divided by the lower confidence limit [Poole, 2001].
Exposed (1): fishermen who perform task over half the time; referent (0): fishermen who perform task half the time or less.
*Poisson regression estimates are adjusted for multiple visits per subject with GEE.

dynamic tasks: number of static tasks including driving the boat, running the puller or net reel, setting gear, sorting catch on the boat or at the fish house, cleaning or maintenance of boat and gear (RR = 1.2, 95% CI 0.9, 1.5) versus number of dynamic tasks including loading or unloading the boat, using a dolly or lift for loading/unloading, and pulling in or emptying gear (RR = 0.9, 95% CI 0.6, 1.3).

When examining the ergonomic characteristics of the 89 crab pot and gill net fishermen, severe LBP increased with mean percent time exposed to forces >20 lb in non-neutral trunk postures, >3,400 N of spine compression, and lifting index >3.0 (Table VI). The rate of severe LBP was unassociated with non-neutral trunk postures, forces >20 lb, manual materials handling, lifting index >1.0, and probability of high-risk group membership >70%. However, these RR represent an increase in risk per 1 unit increase in the percent of time exposed. An increase from 10% of time to 20% of time (10 unit increase) in the percent of time in non-neutral trunk postures resulted in a RR of 1.40.

DISCUSSION

In this cohort of small-scale crab pot and gill net fishermen differences were observed in the occurrence of severe LBP by self-reported fishing task (Tables IV and V) and by ergonomic low back stress assessment (Table VI). Operating pullers and net reels, using a dolly or lift to unload catch and supplies, and sorting catch on the boat were strongly associated with severe LBP. Dose–response for task frequency was not observed in this group nor was there a difference observed between static or dynamic tasks. Ergonomic measures associated with the occurrence of severe LBP in this study included forces >20 lb in non-neutral trunk postures and levels of spinal compression >3,400 N and lifting index values >3.

Results for PATH and CABS measures generally supported the independent self-reported task findings. Sorting catch on the boat, a task characterized by static, awkward postures and repetitive motions performed extensively by a

TABLE VI. Crab Pot and Gill Net Fishermen: Unadjusted Rate Ratios and 95% Confidence Intervals for Mean Percent Time Exposed to Low Back Stress and Low Back Pain Occurrences That Interrupted or Limited Work (n = 89, 313 Visits)

	Fishing type	Percent time exposed to low back stress[a], mean (SE)	Inter-quartile range	Parameter (SE)[b]	RR (95% CI)	CLR
Posture, Activity, Tools, and Handling (PATH)						
Non-neutral trunk posture	Gill net	24.04 (7.58)	14.0	0.0337	1.03 (0.96, 1.11)	1.2
	Crab pot	25.64 (5.35)	13.5	(0.0359)		
Force >20 lb (9 kg)	Gill net	9.78 (3.82)	3.0	0.0820	1.09 (0.92, 1.28)	1.4
	Crab pot	10.93 (2.10)	10.0	(0.0852)		
Handling materials[c]	Gill net	39.16 (7.98)	13.0	0.0079	1.01 (0.98, 1.04)	1.1
	Crab pot	23.91 (5.12)	20.0	(0.0150)		
Non-neutral trunk and force >20 lb (9 kg)	Gill net	2.70 (0.99)	2.0	0.2886	1.33 (0.76, 2.36)	3.1
	Crab pot	3.19 (0.57)	3.0	(0.2903)		
Continuous Assessment of Back Stress (CABS)						
Spine compression >3,400 N[d]	Gill net	0.54 (2.61)	1.5	0.1591	1.17 (0.91, 1.50)	1.6
	Crab pot	3.79 (1.93)	8.7	(0.1267)		
Lifting Index >3.0[e]	Gill net	0.09 (1.47)	0.3	0.2448	1.28 (0.87, 1.89)	2.2
	Crab pot	2.25 (1.12)	4.1	(0.1988)		
Lifting Index >1.0[e]	Gill net	31.14 (11.05)	56.8	0.0133	1.01 (0.97, 1.05)	1.1
	Crab pot	21.67 (7.62)	26.4	(0.0203)		
Probability of high-risk group >70%[f]	Gill net	48.76 (9.37)	33.7	0.0166	1.02 (0.98, 1.05)	1.1
	Crab pot	51.94 (6.10)	23.4	(0.0177)		

CLR, confidence limit ratio, upper confidence limit divided by the lower confidence limit [Poole, 2001].
[a]Mean percent time in low back stress measured in sample of fishermen adjusted with multi-level mixed linear model with three nested variables: fish type, crew nested within fish type, job nested within crew within fish type [Kucera et al., 2008].
[b]Poisson regression estimates are adjusted for multiple visits per subject with GEE.
[c]Lift, lower, carry, push/pull, slide, or hold.
[d]Low back compression measured in Newtons at L5/S1 joint with University of Michigan 3D Static Strength Prediction Program [Chaffin et al., 1987; Chaffin and Erig, 1991].
[e]NIOSH Lifting Index, object weight divided by Recommended Weight Limit [Waters et al., 1993].
[f]Probability of high-risk group membership measured with Ohio State University Lumbar Motion Monitor [Marras et al., 1993].

mate or third man [Mirka et al., 2005; Kucera et al., 2008], occurred more frequently in larger crew sizes and was associated with severe LBP in this study. Likewise, sorting catch at the fish house, a less stressful task for the low back where fishermen work at tables in upright postures, was not associated with LBP. Unloading catch or supplies, with or without a dolly, was a task characterized by high compression and lifting index values in the ergonomic assessment [Kucera et al., 2008]. We observed an association with severe LBP for this task and high compression and lifting index measures. Previous studies of manual lifting occupations have reported unadjusted associations with any LBP and lifting indices from 1 to 2, 2 to 3, and >3 [Waters et al., 1999].

We did not observe an association for loading activities despite the higher ergonomic low back stress reported by fishermen [McDonald and Kucera, 2007] and described in previous work [Kucera et al., 2008]. Similarly, tasks that are not associated with high ergonomic low back stress, running puller or net reel, were also associated with severe LBP. These results likely reflect differences in task performance by fishing type (e.g., gill net fishermen do not use bait; therefore, have less to load). Differences could also be attributed to age and the addition of crew members which could reflect distribution of tasks between captains and mates as well as self-selection into tasks by age or job or previous LBP. Without specific information regarding task selection and temporality, we were limited in our ability to quantify these potential risks.

We observed age and years of experience were associated with the occurrence of severe LBP. Torner et al. [1988] found higher prevalence of LBP for Swedish fishermen age 41–50 but prevalence decreased thereafter. In addition, fishermen with fewer years experience (20–29 years) had more LBP when compared to those who fished over 40 years [Torner et al., 1988a]. We observed similar results for years experience in our subset population. Like the ocean-going Swedish fishermen, many in this cohort started fishing at young ages. However, the age participants began fishing in the current study ranged from 5 to 54 years. Those who started their career later had fewer years experience, and this could explain why we did not see decreasing occurrence rates with increasing age.

Subjective self-reported work-related causes of low back stress have been reported differently by job. Captains have been reported to attribute low back stress to static work postures (driving and running puller) while mates identified dynamic tasks and postures (shoveling and lifting) [Torner et al., 1988a]. Interviews with North Carolina commercial fishermen indicated that loading and unloading bait and boxes of catch were stressful for the low back [Lipscomb et al., 2004; McDonald et al., 2004; McDonald and Kucera, 2007], and we hypothesized that tasks with higher low back stress measured with PATH and CABS (e.g., loading, unloading, pulling or emptying gear, and sorting on the boat) would be associated with severe LBP. However, we found varying results and suspect this may depend on age, whether crew members were present, or whether other fishing types were performed. These fishermen were largely an independent group of workers and often mediate their exposures in many ways including choice of fishing type, addition of crew, decreasing hours on the water or volume of catch set, or task selection [Lipscomb et al., 2004; McDonald et al., 2004; McDonald and Kucera, 2007].

Research such as ours can identify modifiable risk factors and inform interventions to decrease work-related low back stress and ultimately LBP. Modifiable risk factors for fishermen in this study included static, awkward postures for sorting tasks, manual materials handling tasks during loading and unloading activities, and operating pullers and net reels. A participatory ergonomic intervention study is currently being conducted with commercial crab pot fishermen to develop inexpensive tools and equipment to decrease low back stress. Our research indicates that fishermen are willing participants in studies and involving commercial fishermen early on in a participatory capacity is vital to the success of intervention research. This will likely increase adoption of beneficial changes and address recognized worker needs that are cost efficient. This study demonstrated that a multi-disciplinary approach that combined ethnographic techniques and detailed ergonomic assessments with epidemiologic outcome and exposure data can lead to interventions that will hopefully improve the work environment and productivity for commercial fishermen.

Limitations

These findings may reflect a healthy worker effect with those who fished longest having the lowest occurrence of severe LBP. The fishing task results in our study provide some evidence of this self-selection of tasks or addition of crew, because some tasks with higher biomechanical stress values (i.e., loading bait or supplies, pulling in or emptying gear) were not associated with the occurrence of severe LBP. The results obtained when stratifying by history of severe LBP support the hire of crew members to perform the more stressful tasks. However, we could not determine in our data whether fishermen hired crew or selected out of tasks because of previous LBP. Our findings for years of experience are consistent with healthy worker effect reported in other studies of commercial fishermen [Torner et al., 1988a; Lipscomb et al., 2004].

The population recruited for the cohort study included licensed commercial fishermen. However, not all fishermen need a license and most mates are not licensed. Therefore, a self-defined ‘‘mate’’ in the cohort may not be the same as the ‘‘mates’’ for whom we measured biomechanical stress with PATH and CABS [Kucera et al., 2008]. They were largely unlicensed, young workers employed to help the captains. This should be kept in mind when trying to generalize results.

We do not have complete information on everyone in the cohort; therefore, our analysis was limited to the 105 who answered the supplemental questionnaire and supplied information on fishing work history. Our task and ergonomic analyses were restricted to the 89 crab pot and gill net fishermen reducing precision further. Small sample size limited our ability to look at combined effects with a multivariate model in our analyses, illustrated by the wide confidence intervals. Supplemental questionnaire participants reported a higher occurrence of severe LBP compared to the whole cohort, which provides some evidence for possible selection bias.

Commercial fishermen are a dispersed workforce and difficult to reach with traditional research methods. Individual exposure assessment was not possible and beyond the scope of this study. Therefore, we used previous PATH and CABS exposure measures from a group of fishermen (n = 25) [Kucera et al., 2008] to estimate individual ergonomic stress in crab pot and gill net fishermen who answered the supplemental questionnaire. Group assignment of exposure can lead to misclassification of exposure and potential bias in our estimates.

There were risk factors known to be associated with low back stress and low back pain that we were unable to examine in our study. We did not measure biomechanical stress of other fishing types or non-fishing-related work but examined variables to explore these effects. Previous studies have reported boat motion increase musculoskeletal strain for fishermen [Petersen et al., 1989; Torner et al., 1994]. We observed this qualitatively; however, magnitude of motion is affected by weather and self-correction, and we were unable to account for this variable in our analyses.

Strengths

This study had many strengths. We were able to estimate in a unique population of small-scale, independent commercial fishermen the association between the occurrence of severe LBP and crab pot and gill net fishing tasks and biomechanical low back stress. This is the first study to use ergonomic commercial fishing work exposure measures accounting for variation between crew sizes and job types in a predictive model.

A prospective cohort design was employed to assess LBP and fishing types performed over a 2-year follow-up period. Previous studies of LBP in commercial fishing utilized cross-sectional and retrospective designs [Torner et al., 1988a; Norrish and Cryer, 1990; Jensen et al., 2005]. Use of a prospective cohort design generally decreases the chance of survivor bias.

Detailed interviews with commercial fishermen from the ethnographic study furthered our understanding of the fishing process and informed our ergonomic analysis. Together with the detailed epidemiological data from telephone interviews and clinic visits, this study had a broad and rich context from which to study low back pain associated with commercial fishing work. Most of commercial fishing research has been conducted with large-scale fishing operations, but relatively little is known about small-scale fishing operations such as those studied here.

CONCLUSION

Our results demonstrate that neither fishing task frequency nor ergonomic measure alone consistently predict LBP. History of LBP, addition of crew members, and likely self-selection out of tasks were important contributors to low back stress and outcomes. We observed variability in the way fishing work was conducted but were limited in our ability to account for reported differences in our analysis. Possible explanations for this discrepancy are revealed by the fishermen themselves. Fishermen who said they changed the way they fished due to LBP did so by doing less stressful work (e.g., lifting less or work slower), being more careful, using or bending legs when lifting, and lifting with help. Several reported using a puller or net reel, a back brace, anti-fatigue mat, or a longer pole while some adjusted the sorting table height or changed the way they shook the crab pot. One fisherman reported re-outfitting the boat to fish off the port (left) side. We can only speculate as to how these modifications might mediate or prevent severe LBP. Future research should focus on both stressful tasks identified with ergonomic assessments and tasks associated with LBP (e.g., sorting catch, loading and unloading, maintenance work). It is important to know how and why fishermen might adjust their exposures to low back stresses.

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