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RESEARCH ARTICLE

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Injury, illness, and disability risk in American seafarers

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Background: Seafarers are an understudied and essential workforce, isolated from medical care. This study describes injuries, illness, and risk factors for resultant disability in one shipping company with a majority of American seafarers.
Methods: The study used a telemedicine database of injury and illness incidence in seafarers, and applied descriptive statistical methods and logistic regression modeling.
Results: Illnesses were more frequently reported than injuries (860 vs 479). The overall injury rate was 113 per 1000 person-years, and the overall illness rate was 211 per 1000 person-years. Seafarer ratings had higher risk for disability compared to officers (OR = 1.60; 95%CI 1.17, 2.18), and incidents on dry cargo ships (OR = 2.70; 95%CI 1.49, 4.91) and articulated tug-barges (ATBs) (OR = 2.21; 95%CI 1.26, 3.86) had higher disability risk compared to container vessels.
Conclusion: Additional research in this vital American workforce may be useful to confirm these findings forming a basis for preventive interventions.

KEYWORDS
disability, maritime, occupational injury, seafarer, telemedicine

1 | INTRODUCTION

"The cook onboard feels sick today. Seems like he has cold/flu like symptoms. He is tired, congested and has a cough. He doesn't want to see a doctor yet. He has taken some of his own Nyquil and Dayquil. I have aspirin, pseudoephedrine, and Robitussin."

"Seaman relieved of watch on Bridge. Went to cabin three decks below; returned 3 minutes later and went into collapsed state on bridge exhibiting signs of convulsive seizure."

"Third Engineer got something in his eye. I inspected the eye with a magnifying glass and saw nothing in the eye. The eye is clearly irritated."

"Muscle pain, soreness in his upper left arm. He had been descending a ladder way in the engine room and slipped, falling the last few feet. He caught himself by gripping the handrail and felt a pain in the upper arm muscles."

These are some of the telemedicine advice calls from ship captains to land-based medical advisors, illustrating occupational hazards, emergency medical conditions, routine primary care conditions, and limitations to assessment and treatment options in seafarers working isolated from medical care. Typically, seafarers can be on contracts for 6-10 months at a time, working in shifts but living on the vessels, and so seafarers never actually leave the workplace and hazards behind when their shift is over. In addition, shore leave can be challenging due to visa restrictions and short turnaround time at port. Working isolated at sea, seafarers enable 90% of global commerce,[1] and there are approximately 1.6 million seafarers around the world.[2] In the United States

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(US) there were 36 720 boat captains, mates, and pilots, 32 530 sailors and marine oilers, and 9750 ship engineers, of whom most were employed on inland waterways, coastal, deep sea, and Great Lakes transportation industries in the year 2016.[3]

Seafaring work is typically segregated by department, between the deck (including watch keeping, vessel upkeep, cleaning, and painting, line handling), engine (including monitoring and management of engine mechanism, cleaning, and painting the engine, fueling), and galley (including food preparation, dishwashing). Although work at sea has been qualitatively described to be inherently riskier than many land-based work environments,[4] occupational health research on working seafarers is limited. The sparse medical research to-date on this essential working population has been largely limited to mortality studies; determinants of at-sea injury, illness, and disability remain largely undescribed, likely due to poor access to data on this medically isolated workforce.[5] For example, a study of American merchant seafarer mortality patterns identified high rates of respiratory cancer and overall cancer deaths, pointing towards potential occupational and behavioral risks specific to merchant seamen.[6] More recently, telemedicine has expanded medical access to this vulnerable population, and telemedicine datasets have provided key information on seafarer medical incidents in their work environment.[7–11] While telemedicine access for working seafarers continues to expand, studies of medical events in seafarers remain limited by available data, and to our knowledge only one study has described at-sea medical conditions occurring on US-flag vessels.[9] Our study evaluates an essential US workforce, US seafarers on large ocean going vessels as well as smaller inland vessels (tugs and barges), and identifies areas of potential preventive interventions by occupational environmental determinants.

The vessels in this study include a diverse cross-section of transport vessels representative of the shipping industry. Tugs and barges generally operate on the inland and coastal waterways, with bulk transportation on barges pushed by tugs and tows. Container vessels are large ships transporting thousands of tons of material in containers enabling simple on- and off-loading. Cargo and bulk carriers may transport many thousands of tons of materials as well. Tankers are more specialized vessels designed for carrying liquid cargo, which may include petroleum and other liquid chemicals; there are even a few tankers around the world that transport liquid orange juice and orange juice concentrate. RoRo (roll on/roll off) vessels are used to transport vehicles and other cargo that are rolled on or off the vessel rather than lifted by a crane at port. Civilian companies may also manage military vessels for logistical support, and this company managed certain non-combat military vessels with civilian crews.

This is a retrospective study of telemedicine case records of predominantly US seafarers crewing multiple vessel types for one shipping company over a recent 2.5 year period. The authors describe the distribution of injuries and illness and resultant disability in the seafarer population, and present calculated incidence rates. In addition, demographic and occupational risk factors for disability due to at-sea illness and injury were explored. While there is little comparative research to-date on US seafarers, this study may serve as a baseline for comparing future trends determined in larger occupational health studies.

2 | MATERIALS AND METHODS

2.1 | Data

The research protocol was approved by Yale IRB. The study used the medical case database from Future Care, Inc., a telemedicine case management company servicing seafarers and shipping companies, inclusive dates between January 2014 and July 2016. The subset of medical case data included in the study consisted of all cases arising on vessels of one company with a significant majority of seafarers being US nationals. The data included demographic information for seafarers with injuries or illness occurring while working on their vessels (age, sex, nationality), as well as occupational variables (worksite, rank), fitness for duty determination (full duty, limited duty, unfit for duty), and vessel type. Injury diagnosis and injured body part, and illness diagnosis and illness category were included in the database as well

2.2 | Analysis

Descriptive analysis of seafarer demographic and occupational variables was performed to demonstrate distribution of injury and illness diagnoses, as well as demographic and occupational characteristics among injury cases, illness cases, and cases with disability. Rates of injury and illness were calculated by dividing the number of cases by the calculated at-risk population and expressed as an average annual cumulative incidence over the study period. The at-risk population was calculated by multiplying the number of vessels included in the telemedicine services contract by the typical average number of workers per vessel for each vessel type. Larger ships, including container vessels, general cargo, tankers, RoRo vessels, and military (civilian sealift command) have an average crew of 20 per vessel. Smaller vessels, such as tugs and tow boats (which tow and move barges or larger vessels), and articulated tug-barges (ATB), have an average crew of six (can range between 4 and 9 depending on specific operations). These numbers were based on knowledge of the industry and consistent with prior studies by the authors.[7,12]

Comparisons were tested for statistical significance using χ^2 or Fischer exact test for categorical variables, and *z*-test for proportions comparisons as according to Rosner.[13] Unadjusted as well as parsimonious logistic regression models were developed to model odds of disability after injury or illness events using the data for injured and ill seafarers in the database. The first adjusted model included all main effects. The parsimonious model was developed by initially including all main effects (age, sex, nationality, worksite, rank, and vessel type) as well as all 2-way interactions, and then a backward elimination strategy was utilized with a significance level-to-stay of $P = 0.05$. All data analyses were performed using SAS v9.3 (Copyright SAS Institute Inc., Cary, NC).

3 | RESULTS

There were 1339 total cases, including 860 illness cases (68%) and 479 injury cases (32%) over the 2.5 years of the study (Table 1) which

TABLE 1 Baseline characteristics of seafarers with injury and illness

	Total		Injury		Illness	
	n	%	*n*	%	*n*	%
Age group						
<30	219	16.4	76	34.7	143	65.3
30-39	219	16.4	81	37.0	138	63.0
40-49	256	19.1	81	31.6	175	68.4
50-59	373	27.9	141	37.8	232	62.2
>60	272	20.3	100	36.8	172	63.2
Sex						
Male	1203	89.8	436	36.2	767	63.8
Female	136	10.2	43	31.6	93	68.4
Nationality						
USA	1290	96.3	460	35.7	830.0	64.3
Other	49	3.7	19	38.8	30.0	61.2
Worksite						
Deck	717	53.5	252	35.1	465	64.9
Engine	337	25.2	124	36.8	213	63.2
Galley	158	11.8	56	35.4	102	64.6
Unknown	127	9.5	47	37.0	80	63.0
Rank*						
Officer	446	33.3	141	31.6	305	68.4
Rating	766	57.2	291	38.0	475	62.0
Unknown	127	9.5	47	37.0	80	63.0
Vessel type						
Tug	436	32.6	162	37.2	274	62.8
ATB[a]	182	13.6	71	39.0	111	61.0
Tanker	176	13.1	61	34.7	115	65.3
Military	175	13.1	49	28.0	126	72.0
Container	145	10.8	49	33.8	96	66.2
Cargo	117	8.7	51	43.6	66	56.4
RoRo[b]	49	3.7	14	28.6	35	71.4
Barge	43	3.2	14	32.6	29	67.4
Small boat	5	0.4	1	20.0	4	80.0
Unknown	11	0.8	7	63.6	4	36.4

[a]Articulated tug-barge.
[b]Roll on/Roll off ship.
*$P < 0.05$ by Chi-square test.

included 4100 person-years of follow-up. There was no significant difference in distribution of illness versus injury cases by demographic and occupational factors except for vessel type, where articulated tows/tugs, and general cargo vessels had higher proportions of injuries compared to illness than other vessels, and military vessels had lower proportions of injuries compared to illnesses (Table 1). As shown in Figure 1, for the seafarers with injury, the most frequent categories of injured body part were upper extremity ($n = 164$, 34%), lower extremity ($n = 107$, 22%), and back ($n = 101$, 21%). The upper extremity injuries included 84 wrist and hand injuries, and 80 shoulder and arm injuries; lower extremity injuries included 50 knee injuries, 14 ankle injuries, and 43 injuries to other parts of the lower extremity. The most frequent illness diagnoses were dental ($n = 224$, 26%), respiratory ($n = 160$, 19%), dermatological ($n = 118$, 14%) and gastrointestinal ($n = 104$, 12%; Figure 2). Common dental diagnoses included toothaches (82 cases), fractured teeth (73 cases), and lost or loose teeth (29 cases); common dermatological diagnoses included infections like cellulitis (20 cases) and abscess (10 cases), fungal infections (7 cases), and herpes zoster (2 cases), as well as non-specific dermatitis and rashes (46 cases); gastrointestinal diagnoses included 31 diarrhea/enteritis cases, 16 upper-gastrointestinal tract conditions including gastroesophageal reflux and esophagitis, and two cases of appendicitis, among other conditions. Respiratory conditions were mainly upper respiratory illnesses (109 cases) including pharyngitis and sinusitis, six cases of asthma/allergic conditions, and the remainder bronchitis (19 cases) pneumonia (5 cases) and other lower respiratory conditions.

Injury cases, as opposed to illness cases, more frequently resulted in lost work (Table 2). In addition, officers were more frequently determined fit for full duty (81%) compared to the lower-ranking seafarer ratings (74%; χ^2, $P < 0.05$). Disability also varied significantly by vessel type, with cargo ship workers losing work due to injury or illness in 64% of cases, while barge workers lost work in only 12% of cases (χ^2, $P < 0.05$).

The distribution of specific injury and illness categories with resulting disability determination are shown in Table 3. Among cases with disability, illnesses consistently resulted in higher proportions of unfit for duty (and therefore, were repatriated) rather than fit for light duty. Injury cases with disability were more evenly distributed between fit for light duty and unfit for duty. Of note, certain conditions were disproportionately associated with being unfit for duty, including toothaches ($n = 8$, 62% of dental unfit for duty cases, compared to $n = 59$, 32% of full duty cases, $P < 0.05$) and kidney stones ($n = 7$, 70% of genitourinary unfit for duty cases, compared to $n = 5$, 10% of full duty cases, $P < 0.05$), while chest pain was not disproportionately associated with being unfit for duty ($n = 6$, 67% of cardiovascular unfit for duty cases, compared to $n = 7$, 47% of full duty cases, $P = 0.34$).

Injury and illness types were overall similarly distributed among officers and ratings from all three worksites (Table 4). The overall injury rate was 113 per 1000 person-years, and the overall illness rate was 211 per 1000 person-years. Specific rates of injury and illness by vessel types are shown in Table 5. ATBs had the highest rates of injury (278 per 1000 person-years) and also the highest rates of illness (435 per 1000 person-years).

Noting a significant difference in the distribution of disability by seafarer rank and vessel type, we modeled risk of disability by age group, sex, nationality, worksite, rank, and vessel type using logistic regression. Our analysis found a significant effect of seafarer rank and vessel type, which remained significant when adjusting for all other factors and all two-way interactions. Seafarer ratings were more likely than officers to have injuries or illness resulting in disability (OR = 1.60; 95%CI 1.17, 2.18), and injuries and illness occurring on dry cargo ships (OR = 2.70; 95%CI 1.49, 4.91), and ATBs (OR = 2.21; 95%CI 1.26, 3.86) were significantly more likely to result in disability compared to container vessels (Table 6).

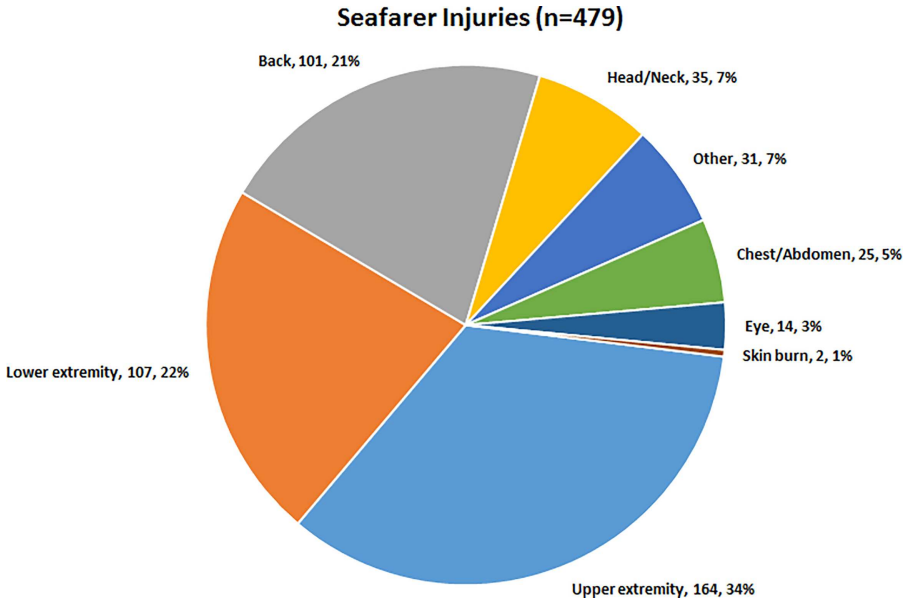

FIGURE 1 Distribution of seafarer injuries by injured body part (n = 479)

4 | DISCUSSION

This study offers a description of injury and illness incidence in US seafarers, an understudied workforce essential for domestic and international commerce. There is little comparable research regarding the health of US ocean-going seafarers or mariners on inland or coastal tugs, towing vessels, and barges. While comparable data is limited, it is notable that the data confirmed that medical illnesses were the primary cause of telemedicine consultation, as opposed to injuries, a finding similar to McKay's study of US seafarer telemedicine consultations by another service provider from 2001 to 2005.[9] The high rate of illness among the population demonstrates that medical illness remains a significant problem in seafarers, consistent with limited prior studies investigating seafarers illnesses.[14–17] In addition, we found that although a higher proportion of injury cases resulted in lost work, illness cases more frequently resulted in complete work disability rather than limited duty. In addition to comparisons from the wider literature here noted, the above findings are also similar to our previously-published results in international seafarers.[7,12]

Importantly, as workers in a remote environment, seafarer disability may not only result in significant morbidity and loss of income, but also increased work demands on fellow workers. Therefore, prevention of injuries and illness in seafarers is of great importance. The distribution of illness and injury cases described in

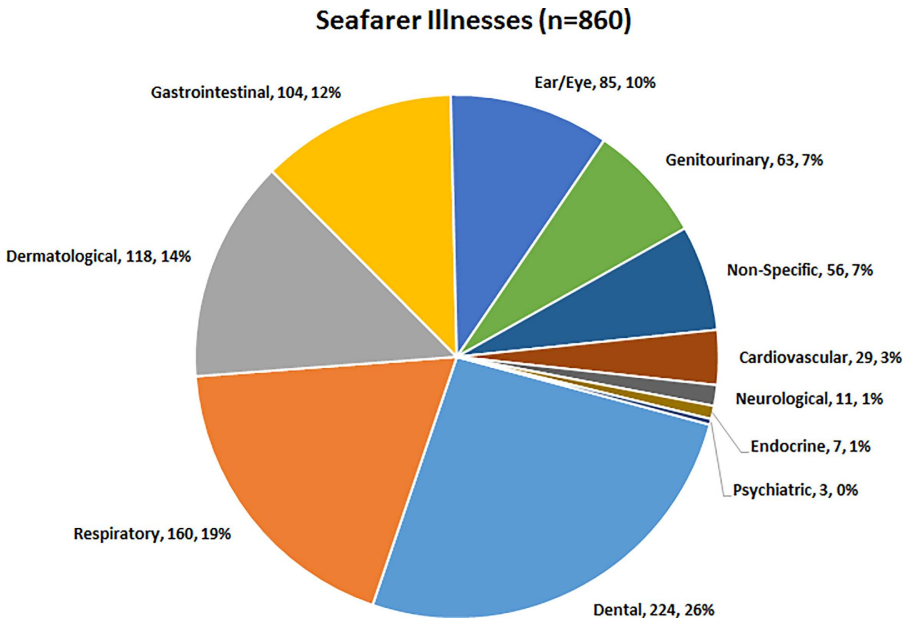

FIGURE 2 Distribution of seafarer illnesses by disease category (n = 860)

TABLE 2 Characteristics of seafarers with injury and illness by work status

	All[a]		Full duty		Light duty		Unfit for duty	
	n	%	*n*	%	*n*	%	*n*	%
Age group								
<30	213	17.1	164	77.0	24	11.3	25	11.7
30-39	208	16.7	162	77.9	20	9.6	26	12.5
40-49	241	19.3	184	76.3	20	8.3	37	15.4
50-59	340	27.2	251	73.8	29	8.5	60	17.6
>60	246	19.7	184	74.8	24	9.8	38	15.4
Sex								
Male	1121	89.8	845	75.4	104	9.3	172	15.3
Female	127	10.2	100	78.7	13	10.2	14	11
Nationality								
USA	1202	96.3	911	75.8	109	9.1	182	15.1
Other	46	3.7	34	73.9	8	17.4	4	8.7
Worksite								
Deck	667	54.3	506	75.9	63	9.4	98	14.7
Engine	321	26.1	248	77.3	28	8.7	45	14
Galley	146	11.9	111	76	13	8.9	22	15.1
Unknown	94	7.7	66	70.2	11	11.7	17	18.1
Rank*								
Officer	421	34.3	341	81	23	5.5	57	13.5
Rating	713	58.1	524	73.5	81	11.4	108	15.1
Unknown	94	7.7	66	70.2	11	11.7	17	18.1
Vessel type*								
Tug	419	33.8	321	76.6	25	6	73	17.4
ATB[b]	170	13.7	119	70	25	14.7	26	15.3
Tanker	160	12.9	119	74.4	27	16.9	14	8.8
Military	155	12.5	125	80.6	9	5.8	21	13.5
Container	137	11.1	113	82.5	10	7.3	14	10.2
Cargo	106	8.6	68	64.2	16	15.1	22	20.8
RoRo[c]	46	3.7	34	73.9	4	8.7	8	17.4
Barge	41	3.3	36	87.8	1	2.4	4	9.8
Small boat	5	0.4	5	100	0	0	0	0
Medical incident type								
Illness	814	65.3	671	82.4	35	4.3	108	13.3
Injury	434	34.7	274	63.1	82	18.9	78	18.0

[a]All seafarers with known work status.
[b]Roll on/Roll off ship.
[c]Articulated tug-barge.
*$P < 0.05$ by Chi-square test.

this analysis offers some insight into potential preventive interventions. Dental, respiratory, dermatological, and gastrointestinal illnesses comprised the majority of illness cases at sea. Dental cases, the majority of which were toothaches, may be potentially prevented with improved preventive dental care as well as increased attention to diet and dental hygiene. If lack of access to dental care is a concern, increasing options for dental care when seafarers are at home between voyages and educational initiatives to recognize early signs of tooth decay may prevent painful toothaches at sea, where treatment options are limited and pain can be debilitating with few treatment options.

Regarding prevention of injuries, the most frequent types of injuries were upper extremity (evenly distributed between hand/wrist injuries and arm/shoulder injuries), lower extremity (primarily knee

TABLE 3 Injuries and illness distribution by seafarer work status

	Total[a]		Full duty		Light duty		Unfit for duty	
	n	%	*n*	%	*n*	%	*n*	%
Injury								
Upper extremity	147	33.9	94	63.9	27	18.4	26	17.7
Hand/wrist	78	18.0	53	67.9	14	17.9	11	14.1
Arm/shoulder	69	15.9	41	59.4	13	18.8	15	21.7
Lower extremity	94	21.7	59	62.8	21	22.3	14	14.9
Knee	43	9.9	25	58.1	11	25.6	7	16.3
Ankle	14	3.2	7	50.0	3	21.4	4	28.6
Other	37	8.5	27	73.0	7	18.9	3	8.1
Back	92	21.2	50	54.3	18	19.6	24	26.1
Head/neck	34	7.9	27	79.4	3	8.8	4	11.8
Eye	14	3.2	13	92.9	1	7.1	0	0
Chest/abdomen	25	5.8	10	40.0	8	32.0	7	28.0
Skin burn	2	0.5	2	100	0	0	0	0
Other	26	6.0	19	73.1	4	15.4	3	11.5
Illness								
Dental	215	26.4	186	86.5	16	7.4	13	6.0
Respiratory	155	19.1	124	80.0	8	5.2	23	14.8
Dermatological	111	13.7	98	88.3	1	0.9	12	10.8
Ear/eye	81	10.0	76	93.8	1	1.2	4	4.9
Gastrointestinal	96	11.8	73	76.0	5	5.2	18	18.8
Genitourinary	59	7.3	48	81.4	1	1.7	10	16.9
Non-specific	54	6.6	37	68.5	3	5.6	14	25.9
Cardiovascular	24	3.0	15	62.5	0	0	9	37.5
Neurological	9	1.1	8	88.9	0	0	1	11.1
Endocrine	6	0.7	3	50.0	0	0	3	50.0
Psychiatric	3	0.4	2	66.7	0	0	1	33.3

[a]All cases with known work status.

injuries), and back injuries. There was no description of injury mechanism available in the data; however, seafarer injuries may result from the impact of physical hazards including heavy lifting, overexertion, slips, trips, and falls, and potential ergonomic hazards. The high rates of injury demonstrate the need for studies of seafarer injury mechanisms, as well as improved hazard assessments on water transport vessels, in order to better inform preventive interventions.

The distribution of injuries and illness by worksite was notable for a higher proportion of cases arising in the deck workers, with a relatively low proportion of cases from engine workers. Large ocean-going transport vessels with approximately 20 workers on board typically have nine engine and deck workers but only two to three galley workers. Therefore, engine workers comprised approximately half of the at-risk work force but only a quarter of medical incidents. The reason for this difference is unclear, but may be due to the inherently different tasks performed and associated hazards, improved hazards control in the engine room, engine department safety culture, or other factors. It is also possible that reporting practices may differ by worksite in this study, which could potentially result in bias; however, this reporting difference would have to be consistent across ship types and crew changes over the 2.5 years study period to result in significant reporting bias.

Studies of seafarer injury rates are rare due to the challenge of estimating the population of at-risk seafarers. In this study, by incorporating information on the total number of ships and types of ships under contract for telemedicine services, the investigators were able to estimate the at-risk denominator to determine rates of illness and injury by vessel type. Injury rates were found to be well above those reported among other US industries with high injury rates, and above those nationally reported in the Bureau of Labor Statistics (BLS) water transportation sector.[18] There are many possible reasons for this finding. First, it may be reflective of a higher threshold for recording cases in the BLS. Second, the BLS classification of waterborne transport workers included many workers aside from seafarers and mariners on vessels, and therefore the populations may not be directly comparable. It is also possible that some of the difference in rates is due to underreporting of occupational injury in the BLS, and/or higher

TABLE 4 Injury and illness distribution by seafarer rank and worksite

			Rank				Worksite					
	Total[a]		Officers		Rating		Deck		Engine		Galley	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Injury												
Upper extremity	152	35.3	52	34.2	100	65.8	86	56.6	44	28.9	22	14.5
Arm/shoulder	80	18.6	26	32.5	54	67.5	42	52.5	23	28.8	15	18.8
Hand/wrist	72	16.7	26	36.1	46	63.9	44	61.1	21	29.2	7	9.7
Lower extremity	94	21.8	28	29.8	66	70.2	55	58.5	27	28.7	12	12.8
Knee	47	10.9	13	27.7	34	72.3	25	53.2	17	36.2	5	10.6
Ankle	13	3.0	5	38.5	8	61.5	11	84.6	2	15.4	0	0
Other	34	7.9	10	29.4	24	70.6	19	55.9	8	23.5	7	20.6
Back	85	19.7	29	34.1	56	65.9	51	60.0	25	29.4	9	10.6
Head/neck	34	7.9	11	32.4	23	67.6	17	50.0	13	38.2	4	11.8
Other	28	6.5	10	35.7	18	64.3	19	67.9	4	14.3	5	17.9
Chest/abdomen	23	5.3	7	30.4	16	69.6	15	65.2	6	26.1	2	8.7
Eye	14	3.2	4	28.6	10	71.4	8	57.1	4	28.6	2	14.3
Skin burn	2	0.5	0	0.0	2	100	1	50.0	1	50.0	0	0
Other	28	6.5	10	35.7	18	64.3	19	67.9	4	14.3	5	17.9
Illness												
Dental	201	25.8	66	32.8	135	67.2	107	53.2	63	31.3	31	15.4
Respiratory	150	19.2	74	49.3	76	50.7	99	66.0	39	26.0	12	8.0
Dermatological	109	14.0	42	38.5	67	61.5	63	57.8	30	27.5	16	14.7
Gastrointestinal	95	12.2	45	47.4	50	52.6	61	64.2	21	22.1	13	13.7
Ear/eye	77	9.9	23	29.9	54	70.1	46	59.7	23	29.9	8	10.4
Genitourinary	57	7.3	20	35.1	37	64.9	32	56.1	19	33.3	6	10.5
Non-specific	49	6.3	18	36.7	31	63.3	32	65.3	9	18.4	8	16.3
Cardiovascular	25	3.2	10	40.0	15	60.0	13	52.0	5	20.0	7	28.0
Neurological	8	1.0	3	37.5	5	62.5	4	50.0	4	50.0	0	0
Endocrine	6	0.8	3	50.0	3	50.0	6	100.0	0	0	0	0
Psychiatric	3	0.4	1	33.3	2	66.7	2	66.7	0	0	1	33.3

[a]All seafarers with known rank and worksite.

reporting practices among seafarers with access to telemedical care. The overall population denominator, as calculated in our study, also differs from the method of the BLS calculation, and so comparison may be further limited by such methodological differences. There are several special considerations in using vessel counts to calculate the seafarer at-risk population denominator, including whether or not a vessel is active, accounting for usual shift schedules, and also the fact that seafarers always have some work exposure 24 h a day, 7 days a week whether or not they are on duty, because they do not leave the ship environment while at sea. Our calculation of seafarer person-years is the sum of the products of the typical number of workers per vessel, multiplied by the number of contracted vessels each year for each vessel. This assumes the ships are active all year, and does not account for seafarer work shifts, or the additional workplace exposures occurring outside of typical work shifts, and so differs substantially from the denominator of full-time equivalent used in BLS rates. This may be another important reason for the discrepancy in rates between our study and the BLS.

The US seafarers studied here, together with their international counterparts, are a medically isolated occupational population. Therefore, approaches to reduce the impact of injury and illness in seafarers may include increased remote access to physician advice, improved preparedness with evidence-based medicine chests on board, and risk-factor reduction where possible. Our study suggests that prevention and treatment efforts for illness may focus on dental conditions, particularly improving preventive dental care to reduce toothaches and other advanced dental diseases resulting in seafarer disability. An additional focus may be to understand risk factors for kidney stones in the seafaring population, as such conditions also disproportionally caused lost work. With an improved understanding of determinants of injuries and illness, including individual and occupational risk factors, preventive interventions may be developed

TABLE 5 Rates of seafarer injury and illness by vessel type

Vessel type	Injury cases (*n*)	Illness cases (*n*)	Vessel-years[a]	Crew per vessel[b]	Person-years[c]	Injury rate†	Illness rate†	Combined event rate[c]
Tug	162	274	159.5	6	957	169.3	286.3	455.6
ATB	71	111	42.5	6	255	278.4	435.3	713.7
Tanker	56	120	35	20	700	80.0	171.4	251.4
Cargo	50	67	14	20	280	178.6	239.3	417.9
Container	48	97	24.5	20	490	98.0	198.0	295.9
Military	47	128	34	20	680	69.1	188.2	257.4
RoRo	14	35	32.5	20	650	21.5	53.8	75.4
Barge	13	30	15	6	90	144.4	333.3	477.8
Total number or average rate	462	866	357		4102	112.6	211.1	323.7

ATB, articulated tug-barge; RoRo, Roll on/Roll off ship.
[a]Vessel-years = number of years telemedicine company contracted with each vessel, grouped by vessel type.
[b]Crew per vessel estimated based on industry norms.
[c]Person-years = (Vessel-years) x (crew per vessel).
†Rates calculated as (number of cases) x (1000)/Person-years.

to reduce the incidence and severity of seafarer illness may subsequently reduce seafarer disability and repatriation, as well as ship diversion. Aside from improved health and retained income for the seafarer, this may reduce the significant direct and indirect costs of medical care to ship-owners as well.[19]

The statistical analysis identified two risk factors for seafarer disability, seafarer rank and vessel type. In regards to seafarer rank, lower-ranking ratings were at higher risk of disability, compared to officers. This may be due to several considerations of work on the various vessels. Ratings may be given more hazardous job tasks, and therefore work-related injuries are more severe. In addition, the same illness or injury may be more likely to remove a rating from work, due to the strenuous nature of their work tasks and correspondingly more rigorous functional requirements, compared to officers who may have more sedentary positions whose tasks can be continued despite the same level of medical impairment. Importantly, the increased disability risk among ratings indicates an opportunity for prevention, which may include developing workplace interventions to reduce hazards in the typical work-environment of a rating, as well as targeted educational strategies for these workers. Future studies should investigate vessel and task-specific hazards. Although a recently published study using seafarer self-reported data has given some insight of potential shipboard hazards,[20] data on occupational hazards assessments for seafarers working in the modern shipping environment are limited.[21]

Our model demonstrated a higher risk of disability for seafarers working on cargo ships and ATBs. Noting the higher rates of injury on these vessels compared to others, it is possible that some of the risk of disability on these ships is driven by conditions of the work environment leading to injury. The high overall rates of injury on ATBs, cargo vessels, tugs, and barges, further suggests preventive interventions may initially focus on improving safety on these vessels. However, our findings should also be confirmed with larger studies, and it is also possible that the higher rates of injury and illness we observed on these vessels reflects differential reporting practices, levels of training, or medical fitness among the workers rather than a difference in occupational or other factors. For example, seafarers seeking work on larger cargo vessels, and licensed seafarers, may have to pass stricter medical requirements compared to certain positions on tugs or cargo vessels. With regard to civilian-managed military vessels, it is not known if higher standards are enforced, possibly contributing to a healthier crew at baseline. Of note, our findings of elevated disability risk in cargo vessels was consistent with Hansen's study of disability in the Danish merchant fleets.[22] Future studies in larger seafarer cohorts may confirm that such vessels are at increased risk compared to others, and identify sources of this risk to enable preventive interventions.

TABLE 6 Model: odds of seafarer disability (light duty or unfit)

	Unadjusted			Parsimonious		
	OR	95%CI		OR	95%CI	
Vessel type						
Container	1.00	(Reference)		1.00	(Reference)	
Cargo	2.63	1.45	4.76	2.70	1.49	4.91
ATB	2.02	1.17	3.50	2.21	1.26	3.86X
RoRo	1.66	0.75	3.67	1.69	0.74	3.82
Tanker	1.62	0.92	2.86	1.51	0.85	2.68
Tug	1.44	0.88	2.36	1.65	0.99	2.74
Military	1.13	0.62	2.05	1.05	0.58	1.92
Barge	0.65	0.23	1.84	0.71	0.25	2.02
Rank						
Officer	1.00	(reference)		1.00	(reference)	
Rating (non-officer)	1.54	1.15	2.06	1.60	1.17	2.18

Our study had several notable strengths. Incidence rates of injury or illness in seafarers have only been reported in a few other studies, and no other incidence rates among US seafarers have been recently published. Although this study is limited to one company of predominantly US seafarers, and the actual proportion of US workers in the at-risk population was unavailable in the dataset, this may provide a useful benchmark for future studies in this essential workforce. In addition, our study provided analysis of injury and illness related disability that has been rarely reported in modern seafaring populations.[7,22] This study also included incidence rates stratified by vessel, enabling comparison of risk between vessels and identifying potential targets for additional studies and trials of preventive measures. Finally, our study found seafarer rank to be a determinant of disability seafarers, with lower ranking ratings at higher risk for disability compared to officers, identifying a potential high-risk subgroup of workers.

There were some limitations of the study, due mainly to limitations of the available data. Vessels and clinical diagnoses were classified to the best available knowledge of the telemedicine case managers, who are trained medical first-responders and have experience working with seafarers and their medical providers. The estimation of incidence rates was based on estimated averages of workers per ship based on industry norms, and did not reflect individual crewing levels of the particular ships utilizing the telemedicine services, and lack of demographic and occupational information for the at-risk population precluded determination of injury and illness rates stratified other than by vessel type. Finally, there was limited information available on the individual mechanisms of injury or potential occupational hazards.

5 | CONCLUSIONS

This study describes patterns of injury and illness, incidence rates, and risk for disability in US seafarers, an essential US workforce with little comparable research to date. Notable findings include higher incidence of seafarer injury and illness on cargo vessels, ATBs, tugs, and barges. The adjusted model identified ATBs and cargo vessels as having higher risk for work disability. The significant associations between vessel type and injury, illness, and disability risk demonstrated in this analysis should be further characterized by vessel-specific work exposure assessments. Routine preventive care, including dental care may reduce the incidence of painful dental conditions at sea and resultant disability; similarly, risks of kidney stones should be explored and preventive measures introduced. In the controlled environment of the vessel, encouraging healthy diets and exercise may reduce incidence of cardiovascular disease and related disability in these valuable workers. Overall, this study provides a baseline for future studies to clarify root causes of health risks in seafarers and reduce modifiable risk factors.

AUTHORS' CONTRIBUTION

RYL contributed to analysis, interpretation of data, drafting and revising, final approval of document, and data integrity. MDS contributed to analysis, interpretation of data, drafting and revising, and data integrity. CAR contributed to interpretation of data, drafting and revising, final approval of document, and data integrity.

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ETHICS APPROVAL AND INFORMED CONSENT

Yale School of Medicine IRB determined the study is exempt under 45 CFR 46.101(b)(2).

DISCLOSURE (AUTHORS)

The authors declare no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

Steven B. Markowitz declares that he has no conflict of interest in the review and publication decision regarding this article.

DISCLAIMER

None.

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