Chapter

Cold Water Exposure for Maritime Workers: A Scoping Review

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Abstract

For many of those working in maritime industries, it is very common to be exposed to harsh environments, such as cold water, on a regular basis. We conducted a scoping review on peer reviewed, published papers to summarize the literature on the topic cold water exposure and non-freezing cold water injuries in the maritime industries. First, industry experts were consulted, then a PICO model was created to define the search terms for the review. The initial search produced 690 abstract. Of these abstracts, 14 were considered to be relevant to the review. The scoping review findings illustrated the lack of research that currently exists in relation to cold water exposure in the maritime industries. Within the available, albeit limited, literature, evidence suggests that there are several cold-water injuries that occur in the maritime industries. These include occupational dermatosis, Raynaud's phenomena, finger blanching, and hand numbness. Performance decrements were also reported. The current gaps include a lack of documentation of minor and non-fatal injuries, the amount of exposure, and training protocols. There is a need to improve cold-water training regulations for those working in the maritime industries and for proper injury documentation, both of which can significantly benefit safety.

Keywords: cold-water, safety, maritime industry, cold exposure, injury

1. Introduction

Occupational health and safety is not a new concern, especially for those who work in the maritime industry. Many of the people who work in this industry deal with heavy equipment, risky situations, and various technologies on a regular basis, all the while working in harsh conditions. Cold water is prevalent in these environments, which workers are routinely exposed to. It is important to understand the relationship that the maritime industry has with cold exposure and its effects on workers to ensure that long term health and safety is not being compromised. This scoping review explored the literature on cold exposure in the maritime industries, and its impact on maritime workers.

There are two main types of cold exposure that workers in the maritime industry are exposed to: acute and chronic. Acute occurs when an individual is exposed to cold conditions or an environment once, for a limited period of time. On the other hand, chronic refers to these conditions repeatedly for an extended period of time. Chronic exposure is the primary type that those in the maritime industry experience,

however, both types can lead to an individual experiencing a cold exposure injury while working [1]. These injuries can be broken down into two different categories as well. The most common injury people are familiar with is frostbite, an example of a freezing cold exposure injury that occurs below freezing conditions for an extended period of time. However, it is also possible to experience cold exposure injuries about the freezing point, which are considered to be non-freezing [1]. A non-freezing cold exposure injury occurs from prolonged exposure to wet, cold, non-freezing (between 0 and 15°C) conditions [1]. These injuries generally involve the soft tissues, nerves, and vasculature of the distal extremities, such as the hands and feet. Both cold exposure and its related injuries are concerning because little is understood about the consequences of chronic exposure to cold conditions.

Current literature regarding cold water exposure is primarily limited to research regarding acute instances, including studies conducted by the military. It is strongly supported that acute exposure to cold water can lead to significant deficits in tactile sensitivity, nerve function and motor performance [2–4]. In fact, following acute exposure to 2°C water, participants experienced impairments in both tactile sensitivity and manual dexterity in as little as 90 seconds [4]. Similar decrements in fine and gross manual dexterity also occurred following acute exposure to 10°C water [5].

As stated previously, individuals who work in the maritime industry experience chronic cold-water exposure. Due to this chronic exposure, do individuals habituate to performance in cold conditions? One study indicated that training in cold conditions may improve an individual's ability to work in the cold [6]. Results showed that although the time it took to complete a peg board test did not improve, but participants' accuracy did improve [6]. However, this study did not address the effects of chronic cold-water exposure, such as seen in an occupational setting.

A recent study examined how chronic cold-water exposure impacted tactile sensitivity and motor performance following acute exposure to cold conditions in a group of fish harvesters [7]. The results suggest that individuals with this chronic exposure may experience impaired sensory performance due to nerve impairments in their hands, indicating that rather than developing adaptations to the cold, the fish harvesters experienced non-freezing cold exposure injuries [7]. Sensory deficits related to cold exposure, such as those just reported, often occur over gradually over time rather than all at once. This allows the deficit to go undetected until its effects are more prominent. The sensory findings from this study were unexpected, which raised further questions surrounding the effects of cold water exposure in the maritime industry. Effects such as these can have a serious impact on the abilities and safety of those working in this industry, which led the authors to consider if there are other studies that have investigated this. It was this study that led to the development of this scoping review. Are these exposures being documented in the maritime industry by other research teams?

In order to explore this topic, the authors conducted a literature review. Due to the anticipated limited amount of available literature, a scoping review was determined to be the best methodology for this review paper. A scoping review is a type of review paper that is used to map the existing literature in a field, and is especially useful when the topic has not been extensively reviewed or documented [8]. A scoping review can summarize and disseminate the available literature and identify gaps in the research [9]. There are currently no existing published scoping reviews regarding the documentation of cold exposure in the maritime industry.

The primary purpose of this scoping review was to examine what has been documented regarding cold exposure in the maritime industry in relation to injuries,

training, and general experiences. The results of this review will help direct the focus of future research projects that address the gaps in this area of literature. Our aim is for future research to prioritize both the understanding and improvement of the long-term health and safety of those who work in the maritime industries.

2. Methods

The objectives, inclusion criteria, and methods for this scoping review were specified in advance and documented in a review protocol [10]. Prior to conducting this scoping review, multiple experts from the maritime industry were consulted. This was to ensure that the research questions, and goal of the scoping review, were both timely and industry-relevant. These professionals included a commercial fish harvester, two aquaculture industry professionals, four ship captains, and a former oil and gas industry professional.

In line with the guidelines discussed by Peters and colleagues, two reviewers were involved with this scoping review and developed the scoping review protocol [8]. The methodology for this scoping review followed the standardized framework that was created by Arksey and O'Malley, including advancements made by Levac and colleagues [9, 11]. The following steps were taken for this review: (1) identifying the research question, (2) identifying relevant studies, (3) study selection, (4) charting the data, and (5) collating, summarizing, and reporting the results.

2.1 Research question

In order to address the primary purpose of this scoping review, several research questions were chosen. The research questions for this scoping review were as follows:

1. Are cold exposures in the maritime industry being documented? If so, how?

2. What training protocols related to cold exposure are documented?

3. What injuries have been reported as a result of cold exposure?

2.2 Inclusion criteria

Once the research question was developed, and using the feedback from industry experts, a PICO model was developed to define the search terms and inclusion criteria for the review (see **Table 1**). The inclusion criteria for the population and context of the scoping review was purposely chosen to be general in order to capture the larger

Population	All genders, global, maritime industry
Intervention	Working on cold water in the maritime industry
Comparison	Working on warm water in the maritime industry
Outcomes	Cold water, safety, injury, exposure, comfort, health

Table 1.
PICO model developed as part of the scoping review protocol to define inclusion criteria.

picture of the maritime industry. This review was limited to English-language, peer reviewed, published literature.

2.3 Data sources and search strategy

The initial search for this review was conducted on December 21, 2020. The two electronic databases used for the search were MEDLINE/PubMed (biomedical sciences, 1946-present) and Scopus (1823-present) [12]. The search terms used during the database searches were extracted from the PICO model as seen in in **Table 1**. These search terms included, but were not limited to: cold, cold exposure, hand, extremities, cold temperature, and fisher. Limits were set to ensure the papers would be English-language and that they were specifically related to humans. A librarian from the Marine Institute assisted in the database searches to ensure proper protocol was followed. Manual searches were also conducted using Google Scholar and the Memorial University Library. Following the initial search, multiple manual searches were conducted to determine if new relevant research had been published. This included a search of the reference lists of all relevant reviewed papers.

2.4 Eligibility criteria

The relevance of the papers pulled for the scoping review were evaluated at multiple screening stages. The first level of screening included evaluating the title and abstract of the paper to determine if the paper was related to the maritime industry, health and safety within the maritime industry, and cold exposure. Abstracts that met at least one of those criteria moved on to the next stage, in which the full papers were reviewed. During this screening stage, papers were removed from the review process if they did not specifically address cold exposure in the maritime industry.

2.5 Extraction of results

The data from the relevant papers was next compiled into a chart. This charting table served to analyze the information in the relevant papers and draw conclusions. The information from this chart was used to develop the results of this scoping review.

3. Results

The initial database searches and follow-up manual searches drew a total of 694 abstracts (excluding duplicates), in which 35 abstracts moved on to the next screening stage. During this stage, full papers were studied to determine if they were relevant to the review. For example, if the article discussed training and/or safety in the maritime industry but did not specifically address cold (water) exposure, it was excluded during this stage. Following these screening stages, 12 papers were determined to be eligible for the scoping review. All papers included in the review were peer-reviewed, journal articles. **Figure 1** shows the screening process of how 694 papers were screened down to 12 papers for this scoping review. While this scoping review encompassed the maritime industry as a whole, all of the papers deemed relevant to the review came from either the fish processing or fish harvesting sectors. Of the 12 papers included, 5 came from the fish processing sector and 3 came from the fish harvesting sector.

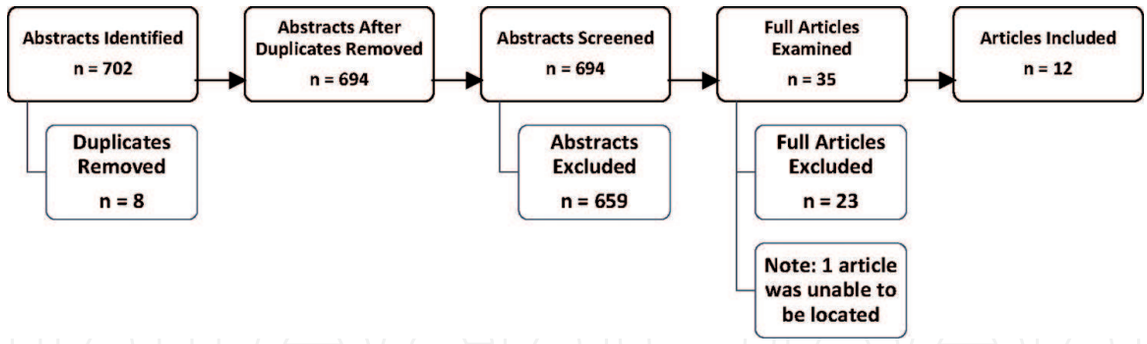

Figure 1.
Flow diagram of screening process for the scoping review.

4. Discussion

4.1 Overview of results

The key finding from this review is that there is a clear lack of cold exposure research specifically related to the maritime industry. As documented in the results, of the 12 papers that were deemed relevant for the review, most of them came from the fish processing and harvesting sectors (n = 5 and n = 3, respectively). 1 paper involved the oil and gas industry, while 3 were based on the general oil and gas industry. The fish processing sector was originally excluded from the scoping review, as seafarers (those who work on the water) were the primary targets for the review. However, due to the volume of papers that arose from the fish processing industry, it became clear that these papers were vital to the review. Unlike what the authors had expected, there was no documentation related to cold exposure training. Due to this low number of relevant papers, it is clear that there is a lack of cold exposure literature related to the maritime industry.

Those in the fish processing and harvesting sectors routinely expose their hands to cold water. For fish processors, common job tasks include cleaning of fish, packing fish for cold storage, peeling shells, cutting squid, and inspecting fish [13, 14]. While the environmental conditions for fish harvesters vary depending on the time of year, and can be unpredictable, air temperatures in fish processing plants have to be kept between 5 and 15°C since the products must be stored in cold conditions at all times [13, 14].

4.2 Cold exposure injuries

Over half the papers (n = 8) within the review documented cold exposure injuries, phenomenon, and performance deficits. While many of the injuries documented in this review are considered to be minor, several of them can have long lasting effects on an individual. For example, one paper on fish processors suggests that moderate cold exposure may be a cofactor in the development of chronic problems with muscles and joints [14]. Other studies from the fish processing industry indicate injuries such as blanching of fingers, Raynaud's phenomenon, decrease in skin barrier function, and occupational dermatosis [13, 15, 16]. As discussed in the introduction, new evidence is also emerging suggesting that those who experience chronic exposure to cold water (in this study, fish harvesters) may experience injuries that result in sensory deficits [7].

There is still much work to be done in injury documentation, especially while considering fatal and non-fatal injury documentation. The focus is often on fatal injuries, which leaves non-fatal injuries and their specific causation to be left undocumented [17]. It was also highlighted that this incomplete reporting has left injury statistics from Maritime Authorities to be unreliable [17]. Of note, this paper was not included in the review as it did not specifically address any elements related to cold exposure. In the fish harvesting industry, the reported rates of injury, fatality, and illness are also limited by the scope and accuracy of the reporting systems [18]. Another paper outside the review states that within the fish harvesting industry, there is a need to prevent severe injuries in fish harvesters while on the docks and on commercial fishing vessels through more active safety monitoring [19]. The consistency in which the maritime industry documents injuries, fatalities, and illnesses must be improved on a global scale.

So, where should the line be drawn for injury documentation in the maritime industry? It is unrealistic to expect that every scrape or minor cut can be documented in the workplace. However, injuries that impact job performance, comfort, and safety should be documented, even if they are considered to be minor. This important for accurate injury reporting, but also for occupational health and safety concerns. As mentioned above, cold exposure (injuries) may lead to future chronic injuries or issues. Therefore, by having all previous injuries documented, researchers can further the understanding of the effects of cold exposure on injuries.

4.3 Effects of cold exposure on performance

While considering the effects of chronic cold exposure on those in the maritime industries, it is important to not only view it from an injury lens, but from a performance lens as well. It is well known that cold exposure can affect performance, including for those who work in the maritime industry. Factors affecting performance (such as fatigue, discomfort, and stress) can affect anyone in many different types of situations. However, performance decrements are especially dangerous for those who work in the maritime industry for multiple reasons. Seafarers often work in dangerous environments, in which a small misstep can have costly mistakes. Additionally, the maritime industry involves a large amount of hands-on work with heavy and advanced equipment. To prevent fatal, and even minor injuries, seafarers have to be consistently aware of their surroundings.

Extreme temperatures can have a severe effect on seafarers' performance [20]. Low temperatures while working may cause fatigue, decrease mental abilities and perception, increase risk of perpetual error, and decrease an individual's ability to identify external elements [20]. In this survey, extreme temperatures had the third highest factor in affecting seafarer's performance of maintenance duties, behind only workload or stress and ship motion [20]. Another study also stated that focus decreased and human error probability increased when work temperatures shifted from normal to extreme [21]. Other deficits related to working in cold environments include a loss of balance, mobility, and strength [22].

Possible cold exposure adaptations were also documented in three of the review papers. For example, the onset of cold vasodilation response was quicker in these individuals compared to their control counterparts during hand immersion in cold water in one study [23]. During another study involving fish harvesters, fish harvesters maintained higher finger temperature and heat flow from their hands compared to their control counterparts during hand immersion in cold water, and

75% of fish harvesters experienced cold-induced vasodilation [24]. Fish harvesters in both studies appeared to experience less discomfort and pain and verbally complained less of pain [23, 24]. In addition, it has been discussed that this adaptation is not just an adaptation to pain in general, but rather to pain caused by cold exposure [25].

4.4 Cold exposure training

Prior to conducting this review, an area of interest for the authors was regarding training protocols have been documented in the literature regarding cold exposure training. However, little to no information on such training has been documented. It was reported that there is a lack of longitudinal studies on occupational health and safety issues in the fish processing sector in Asia [13]. This can be broadened to say that the same is true for the global marine industry as a whole.

During the searching phase of the review, the authors found several papers that discuss the need and importance for more safety training in the maritime industries. While these papers fall outside the scope of the review, they were of interest and therefore, mentioned here. Training courses are a key way in preventing injuries and creating a safer workplace. For example, 'Safety Training & Oceanic Fishing' by suggests that training courses have resulted in individuals using more caution in respect to less severe incidents [26].

5. Implications for research and practice

This scoping review highlights the multiple gaps in maritime industry cold exposure literature. The clear lack of industry relevant research demonstrates a lack of understanding of cold water exposure in the maritime industry. There are several recommendations to make for future literature in this area. First, more literature is needed documenting workers' experiences with cold water exposure. This may include the prevalence of cold exposure in their respective occupations, their understanding of this exposure, whether it's chronic or acute exposure, and what job tasks expose them to cold water. Secondly, the development of a standardized framework in documenting cold exposure injuries in the literature will allow researchers globally to focus their work on the prevalent injuries and further their understanding of the common cold exposure injury risks in the maritime industry. The research conducted related to maritime industry cold exposure cannot be primarily limited to the fish processing and harvesting sectors. This field of research is emerging and it is critical that these gaps are addressed. The goal of our paper is to provide a clear baseline for future research projects on cold exposure in the maritime industry. Using the information in this review paper, future research can target the current gaps in the literature while being industry relevant. Minimizing these gaps will enable both the academic and industry communities to further understand how cold exposure affects maritime workers, creating opportunities to improve their long-term health and safety.

6. Conclusions

With new evidence emerging related to the effects of acute and chronic cold-water exposure, the authors conducted a scoping review to determine how it is understood

and documented in the maritime industry. It is well known that many of the people who work within this industry are commonly exposed to cold (and often wet) conditions. A standardized framework was followed throughout this review, and a PICO model was developed to determine the search criteria. Additionally, the inclusion criteria for this review included English-literature, peer-reviewed, published literature. As expected, there is very little documented regarding this exposure in the literature. Only 15 documents were deemed eligible for the review, indicating a clear lack of research. While the results are limited, there are many research opportunities in this area, and this review documents several recommendations moving forward. For example, calls for standardized injury reporting and more rigid documentation have been made in various maritime sectors, including the fish harvesting industry. It is clear that furthering the understanding of cold-water exposure, creating more in-depth cold exposure training protocols, and improving cold water exposure knowledge is needed. Reducing all types of safety risks, especially those related to cold-water, and increasing transparency and knowledge on the subject will serve to improve the long-term safety in the maritime industry.

Acknowledgements

We would like to thank and acknowledge the librarian at the Fisheries & Marine Institute of Memorial University, Catherine Lawton, for her assistance in conducting the database searches for this review.

Conflicts of interest

The authors declare no conflict of interest.

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