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REVIEW ARTICLE

The physical and psychological effects of occupational noise among seafarers: a systematic review

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ABSTRACT
The aims were to highlight noise levels on board and the health effects of noise on seafarers. Data was collected from multiple databases: PubMed, Web of Science, Scopus, and Ebsco Host. Initially, the search resulted in a total of 197 articles, 16 were chosen. Several ships were found which most sailors had noise-induced hearing loss (NIHL) ($n = 6$). The engine room has been defined as having the highest level of noise. In addition, noise exposure was associated with hearing loss, tinnitus, sleep disturbances, communication difficulties, poor concentration, dizziness, depression, anxiety, headache, fatigue, and stress. Noise exposure is not the only factor that causes health problems: the duration of exposure while working, years of career as a maritime worker, age, lifestyle habits (smoking, alcohol consumption), and even hobbies related to loud sound (such as concert/disco attendance, listen to loud music, etc.) were associated with the adverse health effects experienced by seafarers.

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Health effects; noise exposure; sailors

Introduction

Shipping is the most efficient and cost-effective mode of transport, but it has adverse environmental effects (Peng et al. 2018), and the employees were exposed to the potential hazards of work-related accidents (Febriyanto et al. 2021). One of the newly emerging environmental concerns associated with ships is noise pollution (Putland et al. 2022). It is common knowledge that noise exposure can lead to noise-induced hearing loss (NIHL) and is likely to cause non-auditory health effects (Basner et al. 2014). Moreover, noise exposure has been linked to an increased accident risk (Girard et al. 2009; Muzaffar et al. 2019). Hearing loss can also affect personnel performance and can be identified as a factor in marine accidents caused by human error (Turan et al. 2011). In a variety of industrial and nonindustrial environments, noise-induced hearing loss has been studied (Kurmis and Apps 2007). The variability of noise levels in vessels depends on factors such as vessel type, room dimensions (Bocanegra et al. 2023), and the noise produced by the noise source (Febriyanto et al. 2019). When comparing different classes of ships, it can be observed that container ships produce the highest sound level at a value of 178 dB (Veirs et al. 2016). On the ships, there are numerous types of noise, such as engine, ventilation, and compressor noise (Paddan 2015; Schaal et al. 2019).

The Occupational Safety and Health Administration (OSHA) estimates that US businesses paid over \$1.5 million in noise-related fines and \$242 million in workers' compensation due to hearing loss. Each year, 22 million workers are estimated to be exposed to potentially harmful noise at work (Schaal

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Nicholas et al. 2019). Since 1990, the prevalence of hearing loss has continued to rise throughout the world (Ramsey et al. 2018). Estimates of economic costs due to lost productivity range from $1.8 to $194 billion in the United States, whereas estimates of excess medical costs range from $3.3 to $12.8 billion (Huddle et al. 2017).

Navy personnel at sea have been exposed to excessive noise for many years. Noise has been outlined as a widespread occupational health hazard in the United States Navy, and a high percentage of hearing loss has been recognized (Sunde et al. 2015). However, there have been few reports of sea noise levels in recent years, and the vast majority of these studies have been conducted on fishing vessels and cargo ships (Neitzel et al. 2006; Turan et al. 2011; Zytoon 2013).

The International Maritime Organization (IMO) framework for preventing individuals from harmful noise pressure levels aboard ships; the acceptable noise levels are 85 dBA in work environments, 75 dBA in the engine room, 65 dBA in command and navigation space, and 60 dBA in common areas. The cumulative 24-hour exposure limit cannot exceed 80 dBA per this recommendation (Curovic et al. 2021). Despite the fact that the threshold value for noise on ships has been established, numerous studies on noise intensity exceed the threshold. Among these, Levin et al. (2016) found that the noise level in the engine room of fishing vessels ranged between 94.8 and 105 dBA (Levin et al. 2016). In their study of container ships, Oldenburg et al. (2020) also found an engine room noise level of 110 dBA (Oldenburg et al. 2020). Even though Picu and Picu (2020)"s research indicates that the noise measurements in the navigation room are lower, at 75–80 dBA, they still exceed the predetermined threshold value (65 dBA) (Picu and Picu 2020). Similarly, naval vessels" noise level in berthing rooms (sleeping areas) ranges from 70.3 to 70.8 dBA, which is 10 dBA above the IMO threshold value (Domingo-Pueyo et al. 2016).

Noise that exceeds 85 decibels is damaging to the health of humans. It depends on the duration, frequency of exposure, other influential risk factors and whether the impact will worsen (e.g. gender, ethnicity, body condition, and other causative agents originating from physical, chemical, biological, and other factors) (Domingo-Pueyo et al. 2016). Workers who are exposed to noise will experience hearing impairment (Febriyanto et al. 2019).

In general, understanding and addressing noise exposure among seafarers is of paramount importance due to the global significance of the maritime industry, the paucity of comprehensive research in this domain, the inadequately documented impacts of noise exposure on occupational health among ship crew members, the imperative of regulatory compliance and due diligence, the necessity for international collaboration within this fundamentally international industry, and the economic ramifications stemming from health issues arising from noise exposure. This research holds substantial significance, not only in safeguarding the health and well-being of maritime workers but also in ensuring industry productivity, adherence to international regulations, and the long-term economic sustainability thereof.

The objective of this article is to investigate a comprehensive overview of noise levels experienced on ships and examine the resulting physical and psychological effects experienced by sailors who are subjected to noise pollution.

Material and methods

Review protocol

This study followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) review guidelines explicitly developed for systematic reviews and meta-analyses (Moher et al. 2009).

Inclusion criteria

Before a study could be included in the unit analysis, it had to be done to ensure that certain criteria aligned with the research objectives of this study were met. Firstly, the researchers examine published articles in English between 1982 and January 2023 concerning to occupational noise at the ship, which affects seafarers' health. The criteria for this study exclude articles in the form of reviews, letters to the editor, opinions, conference proceedings, and book chapters. Secondly, the participants must be fishermen, sailors, or any other workers who worked on ships. Thirdly, the variables of this study were health problems experienced by the workers as a result of noise exposure, such as hearing loss, tinnitus, sleep disturbances, communication difficulties, poor concentration, dizziness, depression, anxiety, headache, fatigue, and stress.

Study selection and data search

By searching PubMed, Web of Science, Scopus, and EbscoHost, relevant articles were identified. "Occupational noise" AND "impacts" OR "effects" OR "consequences" AND "seafarer" OR "sailor" OR "seamen" were used as keywords. To round out the information regarding the study population, the authors added the keyword "fisherman." The reviewers reviewed the abstracts and title pages of all identified studies to determine which met the criteria for inclusion. The flow chart of the selection is shown in Figure 1.

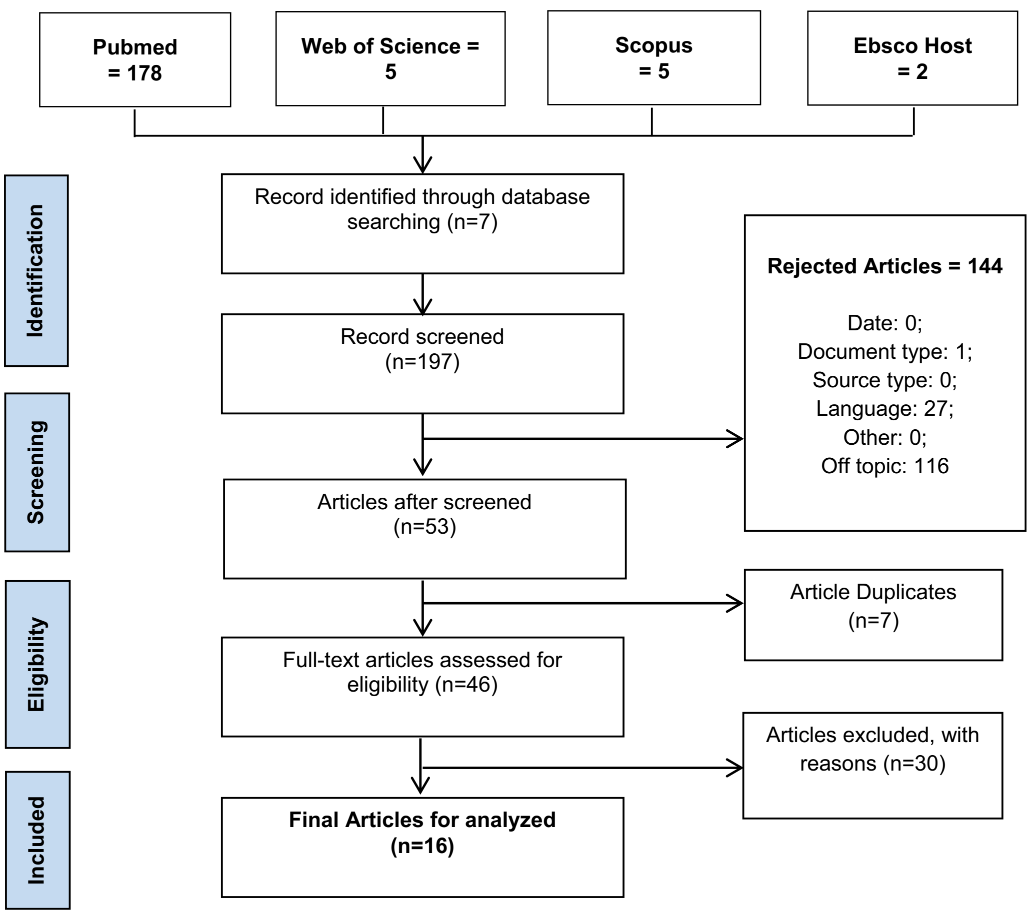

Figure 1. The PRISMA flow diagram.

Data extraction

Following the initial selection, the authors developed a standard form to obtain the following information: (1) the author and year, (2) the country of study, (3) the study population, (4) the type of ship, (5) health problems, (6) noise measurement, (7) frequency of noise, and (7) result of noise assessment.

Results

Basic description

A total of 16 articles were chosen and analysed in relation to the health problems of crew members' occupation noise exposure. The sample size for this systematic review is nearly 300,000 men and women ranging in age from 17 to 67 years. The respondents are fishermen, members of the military, and cabin crew. The characteristics and key findings of the final articles included in this systematic review are summarized in Table 1.

Type of ship

There are several types of ships found by the authors during the review of the article, including navy ships, fishing and merchant vessels, passenger ships, tankers, containers, and others. The majority are European ships (Denmark, Norway, Belgium, Germany, England, and France), and the rest are American, Brazilian, Antigua-and-Barbuda, New Zealand, and Liberian ships as well as ships from Asian nations, including Iran, India, and Thailand.

Health problems

The majority of seafarers ($n = 6$ articles) experienced NIHL. In addition, noise exposure was associated with sleep disturbances, communication difficulties, poor concentration, dizziness, depression, anxiety, headache, fatigue, and stress.

Discussion

The majority prevalent issue in the workplace is occupational noise exposure. Noise-related health problems become one of the most important factors that must be considered. Table 2 explained the Sound Level Meter (SLM) and the Personal Noise Dosimeter are two measuring instruments for noise. The SLM is a device for measuring workplace area noise, whereas the dosimeter measures the personal noise exposure of each worker. Positions were chosen to provide comprehensive coverage of noise sources and locations where noise-exposed workers frequently took up positions. The microphones of the dosimeters are placed on the subjects' shoulders and shielded with windscreens (near the ear) (Neitzel et al. 2006).

Noise exposure can result in various health impacts, both physical and psychological, among sailors. The physical consequences of this phenomenon are hearing loss and tinnitus (Febriyanto et al. 2019), sleep disturbance, and cardiovascular problems (Halperin 2014), such as hypertension and ischemic heart disease (van Kempen et al. 2002; Münzel et al. 2018). Moreover, the psychological implications that have been encountered by the vessel's crew, such as stress, anxiety, and depression (Vukić et al. 2021; Brooks and Greenberg 2022). Seafarers who are subjected to higher doses of noise and vibration are more susceptible to encountering adverse mental health outcomes (Brooks and Greenberg 2022). Stress, anxiety, and depression fall into the classification of psychological disorders due to their impact on an individual's emotional and mental well-being, therefore causing mental health issues (Vukić et al. 2021; Brooks and Greenberg 2022).

Table 1. Characteristics and main findings.

No	Author, year	Country	Study Population	Type of Ship	Health Problems
1	Trost and Shaw (2007)	United States	276,658 sailors, age ranged 17–64 years old	Navy ship	• Permanent hearing loss is the most prevalent disability among sailors.
2	Kaerlev et al. (2008)	Denmark	8,487 seafarers	Passenger ship, tankers, and other ships	• The fishermen and seafarers had the highest rates for NIHL: fishermen= 182, officers = 233, and non-officers = 142
3	Gander et al. (2008)	New Zealand	17 male fisherman	Fishing vessels	• Sleeping disturbances • After sleep at sea, fishermen were significantly more likely to rate themselves as extremely sleepy than after sleep at home.
4	Heupa et al. (2011)	Brazil	52 fisherman, age ranged 24 to 65 years old	Fishing vessels	• Difficulty to understanding speech was 30.77% and 46.15% with tinnitus.
5	Kaewboonchoo et al. (2014)	Thailand	149 males naval officers, age ranged from 20–56 years old	Navy boat	• Hearing loss (39.6%)
6	Irgens-Hansen et al. (2015)	Norway	605 navy personnel (569 were male and 36 female), age ranged from 19–62 years old	Navy vessels	• Hearing loss (31.4%) • Prevalence HL among engine room personnel (38%), navigators were 37%, and electricians (23.6%)
7	Zeigelboim et al. (2015)	Brazil	30 male fisherman, age ranged 33–67 years old	Fishing vessels	• Tinnitus (66.7%), • Dizziness (63.3%), • Hearing loss (53.3%), • Fatigue (36.7%), • Anxiety (23.3%), and • Depression (16.7%)
8	Arumugam et al. (2015)	India	63 fisherman, age ranged 30–50 years old	Fishing vessels	NIHL symptoms: • Hearing loss 28.57% (18 fisherman) • Tinnitus 19.04% (12 fisherman) • Hyperacusis 11.11% (7 fisherman) • Headache 38.09% (24 fisherman) • Sleep disturbances 7.9% (5 fisherman) • Poor concentration 7.9% (5 fisherman)
9	Sunde et al. (2016)	Norway	74 male sailors and 9 female participants, age ranged 18–61 years old	Navy vessels	• Noise exposure had negative impact on seamen's sleep
10	Keller et al. (2017)	United States	36 sailors, age ranged 28 to 44 years old	US Navy ship	• Noise can have a significant negative impact on sailors' communication abilities.
11	Schaal et al. (2019)	United States	60 different location for noise measuring	US Navy ship	• It is predicted that noise levels exceeding 45 decibels in sleeping areas will cause sleep disturbances.
12	Schaal Nicholas et al. (2019)	United States	15 samples for noise measuring	US Navy ship	• Temporary Threshold Shifts (TTS), lead to permanent hearing loss
13	Orru et al. (2020)	Belgium	150 military personnel		• Hearing loss (59.5% was slight and severe was 9.3%) • Tinnitus (66.0%)

(*Continued*)

Table 1. (Continued).

No	Author, year	Country	Study Population	Type of Ship	Health Problems
14	Oldenburg et al. (2020)	Germany, England, Liberia, and Antigua-Barbuda	112 sailors, age ranged 20–62 years old	Container ships	• Stress due to noise (71.8%) was particularly frequent among engine room personnel (83.7%), and significantly less often among deck crew (65.4%). • Many seafarers complained sleep problems during port stay.
15	Esmaeili et al. (2022)	Iran	112 males sailors, age ranged 20- >50 years old	Speed vessels	Four category Hearing Loss based on WHO Guideline: • 75.8% normal (85 sailors) • 18.8% mild HL (21 sailors) • 4.5% moderate HL (5 sailors) • 0.9% severe HL (1 sailors)
16	Lucas et al. (2022)	French	8,308 seafarers	Merchant ship	• Marine engineers were still the workers group with a higher risk of Hearing Impairment. They have an HI close to the definition of socioacousis.

Table 2. Result of noise measurement.

No	Author, year	Noise Measurement	Frequency	Result
1	Trost and Shaw (2007)	n.a.	-	-
2	Kaerlev et al. (2008)	n.a.	-	-
3	Gander et al. (2008)	n.a.	-	-
4	Heupa et al. (2011)	n.a.	-	-
5	Kaewboonchoo et al. (2014)	Sound pressure level (RION NL-21) was used for 10 minutes measurement each area	0.5, 1, 2, 4, and 8 khz	Room: • Main deck: 71 dBA • Control room: 73.1 dBA • Engine room: 100.6 dBA • Rest area: 68.8 dBA
6	Irgens-Hansen et al. (2015)	Sound Level Meter (Brüel & Kjaer Type 2250) was performed for measuring background noise (15 s)	31.5–8,000 hz	Job Category: • Electrician: 106 dBA • Work on deck: 88 dBA • Work in ships office: 36 dBA • Cook: 25 dBA • Work in operation room: 118 dBA • Navigator: 119 dBA • Engine room: 108 dBA
7	Zeigelboim et al. (2015)	The standard exposure level was observed for 8 h with personal noise dosimeter (IEC 651 type 2)	n.a.	Job Category: • Pilot's assistant: 82–94 dBA • Pilot: 97.3 dBA • Deckhand: 87.7–91.1 dBA • Machinery room: 107 dBA
8	Arumugam et al. (2015)	n.a.	-	level of noise from the engine was about 90–100 dB
9	Sunde et al. (2016)	The noise dosimeter (Brüel and Kjaer type 4445) was logged continuously for 1–3 days during the sampling period	-	Noise exposure during sleep was 55.5 dBA
10	Keller et al. (2017)	n.a.	-	-
11	Schaal et al. (2019)	3M™ SoundPro® DL and SE Type 1 SLMs with 1/1 octave band analyzers (Quest Technologies, Oconomowoc, WI, USA) were used to measure noise Levels (4 hr)	16, 31.5, 63, 125, 250, 500, 1000, 2000, 3000, 4000, 6000, 8000, and 16 000 Hz	Leq was 74.6 dBA on average
12	Schaal Nicholas et al. (2019)	3MQuest NoisePro type II noise dosimeters (each area sample logged at least 1,440 min measurements)	-	• The highest Leq was in the fantail social area: 97.7–105.4 dBA • The lowest Leq was in sleeping areas: 70.3–70.8 dBA
13	Orru et al. (2020)	n.a.	-	-

(*Continued*)

Table 2. (Continued).

No	Author, year	Noise Measurement	Frequency	Result
14	Oldenburg et al. (2020)	• Personal: dosimeter type 4445 (class 2) from Brüel & Kjaer • Area: Sound Level Meter type 2250 (class 1) Brüel & Kjaer Two-minute measurement period	-	Location: • Bridge: 45–73 dBA • Office: 40–69 dBA • Deck: 62–80 dBA • Engine room: 98–110 dBA • Engine control room: 56–79 dBA • Workshop: 65–87 dBA • Crew mess room: 46–59 dBA • Galley: 57–73 dBA • Cabin 36–66 dBA • Recreational room: 53–66 dBA
15	Esmaeili et al. (2022)	n.a.	-	-
16	Lucas et al. (2022)	n.a.	-	-

The engine room is expected to have the highest noise levels in the workplace, followed by the engine control room and other areas further away from the ship's engine. In addition, specific job-related tasks produce higher noise levels (e.g. engine repair and manual work on board, such as removing rust) (Oldenburg et al. 2020). According to Table 2, the majority of the time, noise from the boat's engine is constant on fishing vessels (Zeigelboim et al. 2015). Numerous hours are spent in boats by fishermen, and exposure to high noise levels can lead to general and hearing impairment (HI). Levin et al. (2016) discovered that using the SLM resulted in engine room noise levels on fishing vessels ranging between 95.1 and 102.5 dBA (Levin et al. 2016). In Zeigelboim's et al. (2015) research, noise levels ranged from 94 to 107 dBA, revealing similar findings. The machinery room has a maximum decibel level between 91.1 and 107 dBA (Zeigelboim et al. 2015).

The effects of noise exposure on fishermen include poor concentration, headache, tinnitus (Arumugam et al. 2015), dizziness, anxiety, fatigue (Zeigelboim et al. 2015), difficulty understanding communication (Heupa et al. 2011), and sleeping disorders (Gander et al. 2008; Heupa et al. 2011; Arumugam et al. 2015). After sleep at sea, fishermen were considerably more likely to rate themselves as highly sleepy than after sleep at home (Gander et al. 2008).

Navy personnel and fishermen, suffer from sleep disturbances and communication disorders (Sunde et al. 2016; Keller et al. 2017). Communication problems can be inconvenient and potentially life-threatening in high-risk, fast-paced environments if the information is lost, delayed, or inaccurate (Keller et al. 2017). Poor sleep quality and short sleep duration are related to sleep disruption, fragmentation, frequent awakenings, difficulty falling asleep, early awakening, changes in sleep stages, and depth. This is concerning because insufficient sleep can lead to fatigue and worsen poor decision-making, resulting in accidents. During flight operations, personnel working the night shift and sleeping during the day may be more susceptible to sleep disturbances (Schaal et al. 2019).

The noise measurements were taken aboard navy ships, where the average Leq (24-hr): 70.8–105.4 dBA; Leq (operational): 70–101.2 dBA; and Leq (non-op): 39.4–104.6 dBA exceeded Threshold Limit Value. The ACGIH (American Conference of Governmental Industrial Hygienists), CCOHS (Canadian Centre for Occupational Health and Safety), and SOLAS (Convention for the Safety of Life at Sea) recommends a 24-hour noise exposure limit of 80 decibels (Oldenburg et al. 2019; Schaal Nicholas et al. 2019; Burella and Moro 2021). Kaewboonchoo's et al. (2014) research on the Thai Navy Vessel revealed the same thing: the noise level in the engine room was 100.6 decibels (above the threshold value) and less than 85 decibels at other stations (Kaewboonchoo et al. 2014).

In addition, noise measurements on container ships revealed engine room noise levels of 104 dBA, noise levels at the workshop was of 81 dBA, and deck noise levels of 77 dBA. The ship's crew experienced stress due to noise 71.8% of the time, with engine room personnel experiencing stress significantly more frequently (83.7% of the time) than deck crew (65.5% of the time). As expected, this was especially true for the personnel in the engine room, who are subjected to particularly high physical impacts on the job. Numerous seafarers complained in the free-text portion of the questionnaires about significant sleep disturbances in port as a result of the frequently loud container handling and distinctly audible ship movements (Oldenburg et al. 2020).

Environmental and occupational noise is a common problem affecting workers health (Nikolić and Nikolić 2013), such as: hearing loss (Ologe et al. 2006), hypertension, heart disease, irritability, and sleep disturbances (Basner et al. 2014; Zare et al. 2016; Curovic et al. 2021). Hearing damage can be detected early before continued exposure causes irreversible hearing loss (Curovic et al. 2021). Rats with exposure durations between 18 and 24 hours exhibited threshold shifts in an investigation of hearing loss with increasing duration. According to some studies, 12.2% of accidents are attributable to occupational noise exposure and NIHL (Schaal Nicholas et al. 2019).

Navy personnel at sea have been exposed to excessive noise for many years (Sunde et al. 2015). In addition, fishermen and seafarers may also be exposed to multiple sources of loud noises during their work shifts, typically longer than 8 hours per day. Compared to other seafarers and the general population, Danish male fishermen and engine room seafarers have a higher risk of NIHL, and these rates have not decreased over time (Kaerlev et al. 2008). These studies demonstrated that engine room personnel are at a greater risk for developing HI and that fishermen are also at risk for NIHL (Lucas et al. 2022).

Hearing loss was noticeably related to work vulnerability factors: age, years of career in the Navy, years on naval ships in the Navy, and years of shipping, adult otitis, concert/disco attendance, and MP3 player use (Irgens-Hansen et al. 2015). The marine engineers had a typical hearing loss with a notch at 4 kHz, whereas the deck crew had an early presbycusis-like hearing loss comparable to socioacusis. Socioacusis was described as hearing problems caused by exposure to non-occupational noise and lifestyle habits (such as hearing loud music, using power tools at home without hearing protection, etc.) (Lucas et al. 2022).

Individual hearing loss was significantly influenced by both age and work experience (Esmaeili et al. 2022). Even though age, seniority in the profession, and working in the engine room of a commercial ship remain risk factors for NIHL. It is remarkable that the NIHL typical of marine engineers in research published 40 years ago has decreased significantly (Lucas et al. 2022). Several risk factors for HI have been identified for seafarers, suggesting that fishermen and seafarers operating in machine rooms are more susceptible to visiting a hearing health center than other sailors and people (Kaerlev et al. 2008).

Limitations

There were various limitations entailed by this investigation. First, it is important to note that the study's inclusion criteria included potential sources of bias, specifically language bias and publication bias. This is due to the fact that only peer-reviewed journals and papers published in the English language were considered for inclusion. Second, it should be noted that the methodological consistency of the included studies was deemed moderate, as all of them were either observational or long-term follow-up studies. Third, the task of establishing conclusive causal relationships between variables proved challenging due to the predominant use of cross-sectional research designs in the majority of studies. Furthermore, it is important to acknowledge that while noise is indeed a contributing factor to health issues, there are additional confounding variables that must be considered. These variables encompass aspects such as age, duration of employment, exposure to non-occupational noise, lifestyle choices (such as smoking and alcohol consumption), and several other elements that can exert an influence.

Conclusion

This literature review focused on occupational noise exposure and its adverse health effects among seafarers, including fishermen, navy personnel, and other ship crews. In the reviewed articles, noise disturbances in the engine room are higher, and the sailors are more exposed than in other rooms. In addition, noise exposure was associated with physical problems (hearing loss and tinnitus, sleep disturbances, communication difficulties, poor concentration, dizziness, headaches, and fatigue) and psychological disorders (depression, anxiety, and stress). Finally, age, length of employment, exposure to non-occupational noise and, lifestyle habits, several other factors can also contribute to the hearing loss and other health disorders experienced by sailors (such as listening to loud music, using hand tools without ear defenders at home, attending concerts/nightclubs, etc.).

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Authors' contributions

KF designed the study and wrote the paper, with critical revisions from JCCG, FFR interpreted and analysed the data, KF had also a role in data extraction, JCCG editing and supervised the manuscript. All authors have accepted accountability for the entire content of this paper and have given their consent to its submission.

Data availability statement

The datasets is not applicable to this article as no new data were created or analyzed in this study.

Ethical approval

The research conducted is unrelated to human or animal use.

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