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REVIEW ARTICLE

A systematic review on the impact of ship movements on lower back among maritime workers

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ABSTRACT

Purpose: *Working on a ship is challenging for maritime workers. Ship movements and high physical workload on board are straining their musculoskeletal system, which can particularly lead to lower back pain (LBP). The purpose of this study is to review recent studies about the impact of moving environments on the lower back both of seafarers and fishermen and the frequency of related health complaints.*

Methods: *Using a systematic review in the PubMed database, 384 studies about musculoskeletal issues among maritime workers were identified in the period 2000 to 2021. Evaluation of studies was done according to the PRISMA statement.*

Results: *The review revealed 13 studies focusing on musculoskeletal issues of the lower back among maritime workers. Four studies used biomechanical modeling to examine the physical load on board. They all described high physical strain when performing heavy working tasks in moving environments and 2 described the need for compensational efforts due to ship movements. Ten studies examined the musculoskeletal health of seafarers or fishermen and pointed out that particularly fishermen suffer from increased rate of LBP. A comparison of the data of four studies, which comprise prevalence of LBP, depict higher prevalences on fishermen (between 60.95; 95% CI 51.62–70.28 and 82.13; 95% CI 77.23–87.03) than data from land-based population (48.63; 95% CI 46.62–50.64), while the study concerning seafarers showed lower prevalence (28.42; 95% CI 24.74–32.10).*

Conclusions: *The high prevalence of LBP among fishermen suggests that heavy physical work (e.g., operating of fishing nets, filleting process) during ship motions is a strong risk factor. Further studies should evaluate effects of ship movements on the lower back among maritime workers, considering the different activities on board of vessels. As in most physically challenging jobs with repetitive activities, consequent prevention might be a key to lower the morbidity.*

(Int Marit Health 2024; 75, 3: 155–166)

Keywords: musculoskeletal, back pain, seafarer, fishermen

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This is the first review dealing with the impacts of ship movements on lower back among maritime workers. In light of contradictory findings there is an urgent need for subsequent research.
- This review highlights a high prevalence of low back pain in maritime personnel which indicates the high relevance of this issue.
- In spite of a broad search string only few studies often with rather small number of participants could be identified.

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— This review bases on heterogenous studies from different occupational groups in different countries and working conditions. Therefore, general conclusions are limited.

INTRODUCTION

Working on a vessel is associated with several physical and psychosocial stressors for the crew, particularly noise, ship movements, vibration and heat were identified as major physical stress parameters on ships [1]. Working activity in a maritime environment predisposes for a higher rate of incidents [2]. Ships are moving environments and full of metal parts with sharp edges, steep stairways and slippery, wet surfaces. Higher incidence of acute trauma could lead to subsequent chronic disorder and may also influence the overall musculoskeletal health of seafarers [3] and likely fishermen.

Seafarers and fishermen (in this study summarized as maritime workers) experience high physical workload and stress depending on the shipboard occupational groups, vessel types and size. Especially fishermen often perform heavy physical tasks (e.g., shooting or hauling of fishing nets, filleting process) while their vessel is performing strong ship movements. This is because the typically fishing vessels are rather small and ship movements induced by weather conditions are stronger compared to larger vessels [4].

Several studies onshore have revealed an association between high physical workload and increased rate of chronic/ acute musculoskeletal affections, such as back pain or lumbar discopathies [5]. In the maritime context, the ship itself performs movements in all spatial axes during sea voyages (Fig. 1), which may also raise the physical strain especially on the lumbar spine of the seafarers [6, 7].

In Germany among the working population musculoskeletal disorders constitute the largest part of sick work leaves [8]. Over the last decades, these diseases result in massive costs for the German healthcare system, reaching 10% of health expanses in the year 2015 [9]. A total amount of 34.2 billion € was spent on diseases of the musculoskeletal system and connective tissue, of which more than 13% accounted for back pain only [9].

Today, there are several studies trying to assess and quantify possible effects of the working environment of seafarers and Fishermen on their musculoskeletal system; among them cross-sectional surveys were conducted to cover subjective health issues, as well as retrospective studies, based on healthcare data, and field studies [e.g., 10–12]. Some studies point out the stress that ship movements can put on the musculoskeletal system [7]. Despite this, other studies showed that the prevalence of MSD among seafarers was lower compared to land-based working collectives while fishermen depicted a higher prevalence than compared land-based working collectives [13, 14]. This study aims to review the current scientific knowledge about the influence of the shipboard work environment on the lower back of seafarers and fishermen as well as the frequency of respective health impairment.

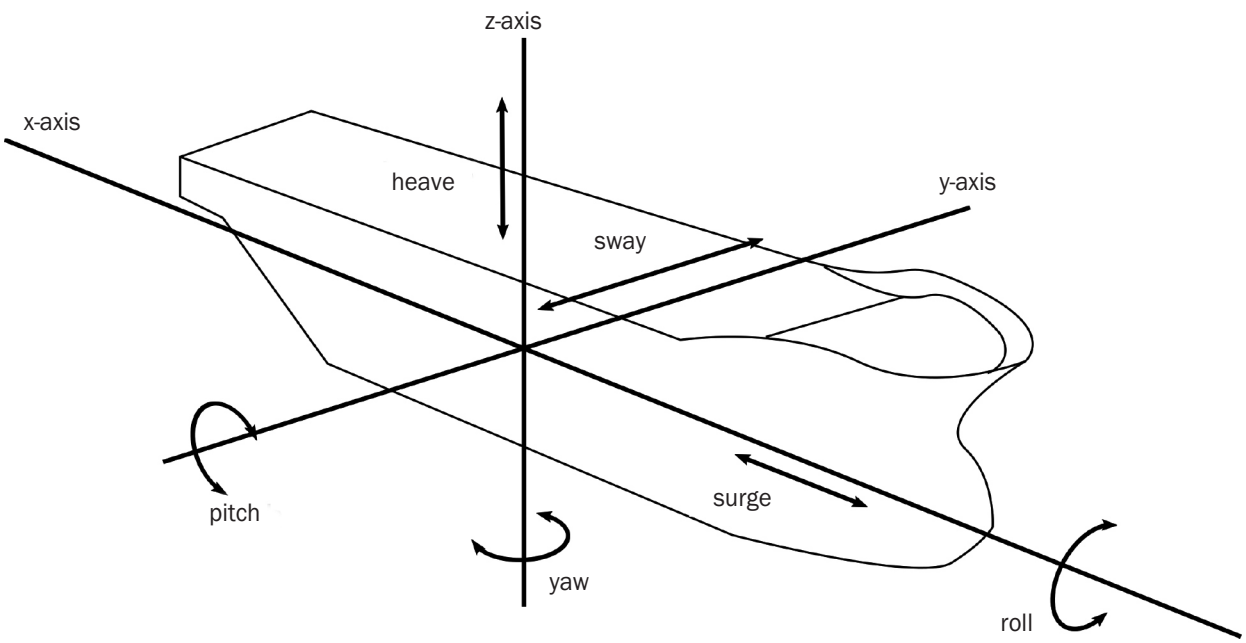

Figure 1. Sketch of ship's axes and movements

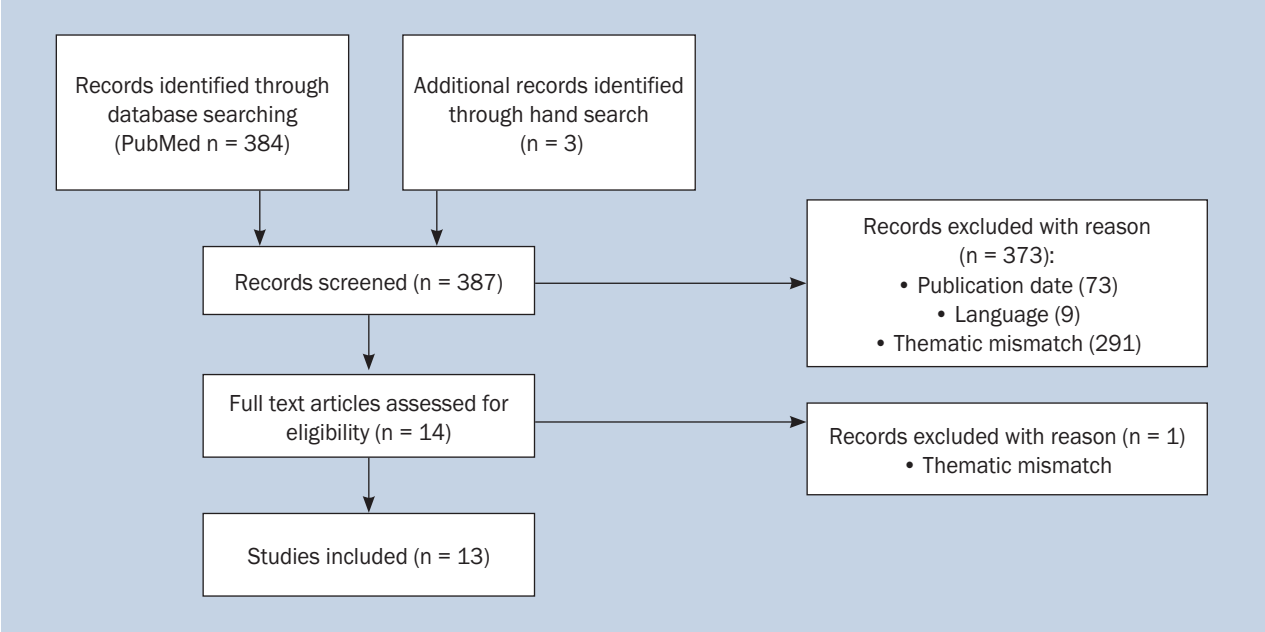

Figure 2. Search strategy for shipboard impacts on the lower back according to the PRISMA Statement (according to Moher, Liberati [15])

METHODS

The systematic review was carried out by three scientists who used the database PubMed and MEDLINE. The last search took place on June 15th, 2023. All three scientists checked independently if the detected studies were suitable to be included in this review. The identification and evaluation of studies took place according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Statement [15].

Scientific studies about musculoskeletal disorders and diseases among maritime personnel were outlined with the following search string: (musculoskeletal OR ergonomics OR posture OR lower back) AND (seafarer OR fishermen OR ships).

Studies that considered acute injuries of the musculoskeletal system were not taken into consideration in this review. Upper limb diseases were also not included in this review as it has been described that ship movements mainly affect the lumbar spine [7].

This term generated a total number of 384 hits and three were manually added. The year of publication ranged from 1964 to 2021. After defining the observation period as publication date not older than January 2000, a total number of 73 studies were not considered for further analysis. Out of this list 9 studies were not written in either German or English language and therefore excluded.

Thereafter, 291 studies were excluded due to thematic mismatch as they did not deal with maritime professions, or they focused on rehabilitation or acute injuries or upper limb diseases. In total, there were 14 studies remaining that underwent further observation (Fig. 2). One of these studies was excluded as it was not related to ship motions. Each of the 13 suitable papers were categorized on type and aim of the study, the examined maritime profession and the examined musculoskeletal aspect of the subject's health (Tab. 1).

All chosen studies were checked for comparable data. In four cohort studies the prevalence of LBP is stated. Preparation of data was not necessary. LBP prevalence data was plotted against each other in a forest plot with confidence intervals (CI) calculated after Wald (Fig. 3). Plotting and calculation of CI was done using R 4.2.2 [16].

RESULTS

The 13 chosen studies include 5 cross-sectional surveys, 3 retrospective cohort-studies, 4 field trials and 1 field study (Tab. 1). Of the 13 studies 8 were published until 2010, and 5 afterwards. Altogether the studies comprise 12 different collectives. Of these collectives, 4 consist of seafarers, 5 of fishermen, 2 on both and one of persons without maritime experience. National background of collectives are as follows: Denmark (3), USA (3), Canada (1), Dutch (1), Filipino (1), Nigerian (1) and Turkish (1). One collective consists of international seafarers from a Norwegian shipping company.

The identified studies generally had two different foci. On one hand, some manuscripts pursued physical characteristics of the ship as a dynamic working environment and how it physically affects the human body. On the other hand, some studies rather described physical effects in different maritime professions, mostly distinguishing between merchant seafarers and fishermen. Therefore, this results section was subdivided accordingly.

Table 1. Overview of included studies

Title	Authors	Year	Aim of study (includes citations)	Type of study	Population	Nationality	Time period	Results (include citations)	Assessment of risk of bias and limitations	Source
Prevalence and predictors of Musculo-skeletal pain among Danish fishermen — results from a cross-sectional survey	Berg-Beckhoff G, Østergaard H, Jepsen JR	2017	To estimate the prevalence and predictors of musculoskeletal pain among Danish fisher-men	Cross--sectional survey	270 fishermen	Denmark	Feb– Apr 2015	More than 80% of the responding Danish fishermen reported low back pain, which in 37% lasted for a mini-mum of 30 days during the past year; middle workload was associated with a 32% (95% CI: 19–46%) and high workload with 60% (95% CI: 46-73%) increased musculo-skeletal pain score compared to low wor-kload. Workload was the only predictor for all pain sites	n is relati-vely small but suffi-cient; study popu-lation is di-vided in skip-per and deck handsandboat types li-miting bias	J Occup Med Toxicol. 15; 11: 51
Effect of ship motion on spinal loading during ma-nual lifting	Faber GS, Kingma I, Delleman NJ, van Dieën JH	2008	Investigation of the effects of ship motion on peak spinal loading during lifting	Field trial	9 healthy ma-les, 6 months experience in ship work			Subjects held their body posture more or less constant with regard to the gravita-tional vertical (no effects in x- and y-axis). Subjects did not time their lifting move-ment in such a way that the effect of ship acceleration on low back loading was reduced. Load reduction by favorable timing of lifts on a ship would be hard to achieve. Z-axis acceleration did affect low back loading, but y- axis acceleration did not. A generalized estimating equations (GEE) regression analysis predicted about 5% increase in total net moment and about 9.5% increase in compression force	Study is ba-sed on extre-mely small and homo-genous po-pulation	Ergonomics.; 51 (9): 1426–1440
Physical activity le-vels among offsho-re fleet seafarers	Geving IH, Jørgensen KU, Thi MS, Sandsund M	2007	To analyze the ha-bits and preferen-ces of seafarers with regard to physical activity	Cross--sectional survey	577 seafarers of a shipping company	Norway		70% of the respondents exercised twice or more times per week when at home, whereas only 39% exercised on board. 20% never exercised on board, and 5% never exercised at home. Preventing illness and injury, a pleasant and inviting gym on board, and keeping weight under control are the three most important motivational factors	n is suffi--cient; study population is not divided in occupatio-nal groups	Int Marit He-alth. 58 (1–4): 103–114

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Table. 1 cont. Overview of included studies

Title	Authors	Year	Aim of study (includes citations)	Type of study	Population	Nationality	Time period	Results (include citations)	Assessment of risk of bias and limitations	Source
Manual materials handling (MMH) in simulated motion environments	Holmes MW, MacKinnon SN, Matthews J, Albert, WJ, Mills S	2008	To examine the increased biomechanical demands associated with MMH tasks performed in moving environments	Simulator study	19 healthy male participants	Canada		Motion induces interruptions (MII) in lifting tasks lead to greater electromyographic signals with increased activity in mm. Erector spinae and external oblique. Lifts during an MII could be very harmful	Study is based on extremely small and homogenous population	SYM B4 Esbjerg 2007
Hospital contacts for injuries and musculoskeletal diseases among seamen and fishermen: A population-based cohort study	Kaerlev L, Jensen A, Nielsen PS, Olsen J, Hannerz H, Tüchsen F	2008		Retrospective cohort study	1994: Fishermen (n = 4,570) Officers (n = 5,061) Non-officers (n = 5,170) 1999 Fishermen (n=3.470) Officers (n=5.375) Non-officers (n=5.867)	Denmark	1994 and 1999	Both fishermen and non-officers have high SIRs for injuries and fishermen also for MSD. Among fishermen, high SIRs for knee arthrosis, thoraco-lumbar disc disorders, injuries were found	n is relatively large; study population is divided in occupational groups for seafarers but not for fishermen	BMC Musculoskelet Disord. 23; 9: 8
Ergonomic risk factors for low back pain in North Carolina crab pot and gill net commercial fishermen	Kucera KL, Loomis D, Lipscomb HJ, Marshall SW, Mirka GA, Daniels JL	2009	To determine the association between LBP that limited or interrupted fishing work and ergonomic lower back stress	Retrospective cohort study	177 commercial fishermen - clinical study, supplemental questionnaire: 105	USA	1999–2001: Clinical study	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 lower back pain (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	Study is based on a relatively small and homogenous population. Health background of population is outlined	Am J Ind Med. 52 (4): 311–321
Use of the CABS methodology to assess biomechanical stress in commercial crab fishermen	Mirka GA, Shin G, Kucera K, Loomis D	2005	Quantification of the biomechanical stresses placed on the lumbar spine during the work activities of commercial crab fishermen	Field study	Three-men crew engaged in crab pot fishing	USA		Significant inter- and intra-crewmember variability. The captain has relatively low stress levels throughout the work day, while the mate performs high force (up to 30 kg), dynamic exertions. The third man of the crew experiences static awkward postures (forward flexed postures held for up to 5 min at a time)	Study is based on extremely small and homogenous population	Appl Ergon.; 36 (1): 61–70

Table. 1 cont. Overview of included studies

Title	Authors	Year	Aim of study (includes citations)	Type of study	Population	Nationality	Time period	Results (include citations)	Assessment of risk of bias and limitations	Source
Occupational health of Turkish Aegean small-scale fishermen	Percin F, Akyol O, Davas A, Saygi H	2012	To examine the health, safety and working conditions of small-scale fishing fleets in the Turkish Aegean Sea coasts	Cross-sectional survey	1,166 small-scale fishermen at Aegeancost	Turkey	2009–2010	984 (84%) experienced diseases of the musculoskeletal system and connective tissue	Study is based on a relatively large population. Results of back injuries do not differ between lower back and other back injuries	Occup Med (Lond).; 62 (2): 148–151
Relation of body mass index and work posture to musculoskeletal disorders among fishermen	Thamrin Y, Pasinringi S, Darwis A, M, Putra IS	2021	To determine the relationship between body mass index (BMI) and work posture/position with musculoskeletal disorders in fishermen	Cross-sectional survey	56 fishermen	Indonesia	2020	The result of the Chi-square test shows that the BMI variable has a p-value of $p = 0.848$. This means BMI has no significant relationship with MSD. Meanwhile, the work posture/position variable has a p-value of $p < 0.001$, which means that there is a significant relationship with MSD	Study is based on a relatively small and homogenous population. The study does not differ between lower back and other MSDs	Gac Sanit. 2021; 35 (S1): S79–S82
Dynamic perception of dynamic affordances: walking on a ship at sea	Walter H, Wagman JB, Stergiou N, Erkmen N, Stoffregen TA	2017	Evaluation of the effects of walking in different directions (fore-aft vs. athwart) on actual walking performance on a ship at sea	Field trial	16 men and women with seafaring experience	USA	January 2016	Participants walked farther along the athwart (short axis of ship) path, than along the fore-aft path without crossing the lateral marks of the path. The pre-judgments by the participants mirrored the observed differences in walking performance. Maritime crewmembers were sensitive to affordances for walking in which the relevant properties of the environment were exclusively dynamic	Study is based on extremely small and homogenous population	Exp Brain Res.; 235 (2): 517–524
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Table. 1 cont. Overview of included studies

Title	Authors	Year	Aim of study (includes citations)	Type of study	Population	Nationality	Time period	Results (include citations)	Assessment of risk of bias and limitations	Source
Limiting low back injuries in Filipino seafarers: The role of the functional capacity exam (FCE) in the pre--employment medical exam	Abaya AR, Enriquez M, Landrito P, Ongchangco JC, Ronquillo RM, Sarmiento RF	2013	Evaluation of the FCE as part of pre- employment medical exam in Filipino seafarers	Retrospective cohort--study	33,616 Filipino seafarers	Philippines	2009–2012	FCE has been significant in decreasing the number of repatriations (6/5572 versus 87/27951) related to back pain in seafarers (relative risk was calculated as 0.346)	Study is based on a very large population. Study population is not divided in occupational groups	Arch Mal Prof. 74 (5): 561
The burden of low back pain among fishermen: a survey in a rural fishing settlement in rivers state, Nigeria	Dienye P01, Birabi BN2, Diete-Spiff K03, Dienye NP4	2016	Determine the prevalence of low back pain (LBP) and explore the coping strategies of fishermen in the Oyorokoto fishing settlement in Nigeria	Cross--sectional survey	384 Nigerian fishermen	Nigerian		68,2% reported lower back pain — mostly associated with marriage (79.5%) and abnormal BMI (73.3%). Fishermen with at least 21 years of experience reported the lowest rate of lower back pain	Study is based on a relatively small and homogenous population. Study population is not divided in occupational groups	Am J Mens Health. 10 (6): NP89–98
Working on a moving surface – a biomechanical analysis of musculoskeletal load due to ship motions in combination with work	Törner, Marianne; Almström, Christian; Karlsson, Roger	1994	Modelling musculoskeletal load on a moving ship at sea	Field trial	Fisherman			Increased musculoskeletal load when working on a moving ship, especially in lower back and lower limbs. The subject performed holding and lifting tasks in both moving and resting environments. Compression forces on L4/L5 increased especially when lifting a 21 kg weight while the ship was moving, namely by 40%	No quantitative comparison possible	Ergonomics 37: 2, 345–362

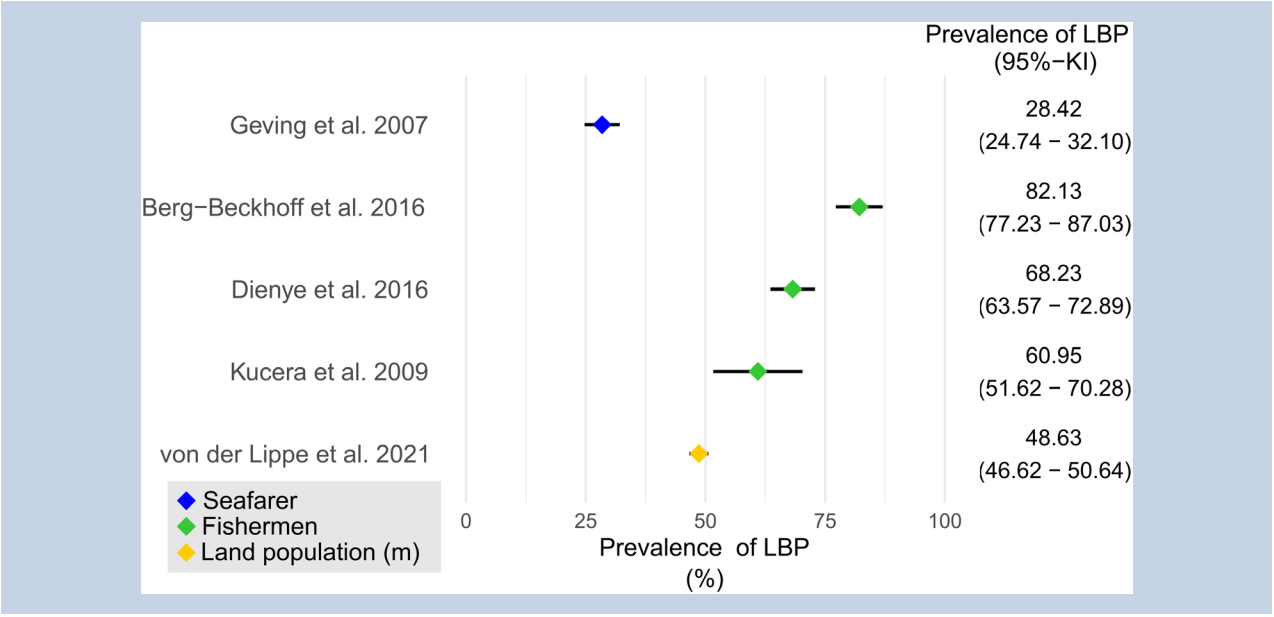

Figure 3. Forest plot of lower back pain (LBP) prevalence from cohort studies on seafarers [blue; 18], fishermen [green; 12, 19, 24] and an additional study on male adult German population [yellow; 25]

SHIP MOVEMENTS AS PARTICULAR PHYSICAL STRESSOR IN MARITIME PROFESSIONS

The search algorithm has identified a small number of studies that had particularly assessed the effects of the ship's movement on the seafarer's health (n = 3). Two of these were field trials, meaning that biomechanical experiments were performed on board of a ship at sea [6, 10]. One study performed biomechanical experiments in a simulator, respectively [11] One further field study from 1997, which was not included by the applied time window, was manually added [7].

Faber, Kingma [6] recruited nine healthy male seafarers for their trial. Each had at least six months experience in working on a ship. The subjects performed different lifting tasks under biomechanical monitoring. The authors concluded that vertical ship movement (heaving, Fig. 1) accounted with a maximum absolute average acceleration value of 0.5 m/s^2. At this acceleration the spinal compression force was increased by 9.5% and the net moment/torque (in newton meter) by 5%. However, lateral (sideward) accelerations of the ship (swaying; Fig. 1) did not affect these parameters since the subjects automatically held their bodies in the gravitational vertical posture. The authors observed that the subjects did not adapt their timing of lifting tasks to the movement of the ship [6].

Walter, Wagman [10] performed a trial with 16 men and women who had 2–38 years of experience in seafaring. The subjects were instructed to perform walking tasks by walking on a 0.3 m wide path of the ships' deck, either in direction of the vessels' x- or y-axis (Fig. 1). Prior to the experiment, subjects were asked to pre-judge how far they might walk on the path without crossing the lateral markings of the path due to the ship's movement. The authors figured that the test persons on board could walk further on the y-axis of the ship without crossing the lateral markings, due to the ships relatively low pitching movements. When walking along the ship's x-axis though, the subjects were exposed to the more intense rolling movements, and therefore could not walk as far without crossing the lateral marks. The authors of the study also observed that the participants could very well judge their walking distance prior to the actual performance, suggesting an awareness of walking challenges in experienced seafarers [10]. Regarding these data the authors concluded that the ship movements seem to force the seafarers to a permanent need of musculoskeletal compensation. However, the intensity of compensation may depend on the direction of the walking paths on the ship.

Törner, Almström [7] conducted a field trial on a single fisherman and described an increased musculoskeletal load during physically work on a moving ship, especially in lower back and lower limbs. The subject performed holding and lifting tasks with a 21 kg load in both moving and resting environments. Under motion, compression forces on L4/L5 rose when holding weight and even more during lifting. Compression peaked at more than 40% increase compared to calm conditions [7].

The latter is consistent with data by Holmes, MacKinnon [11]. The authors conducted a study in a moving ship simulator with 19 healthy male subjects without seafaring

experience. Subjects had to perform lifting tasks with a 15 kg load from ground or from a 250 mm elevated position under biomechanical monitoring. Subjects displayed an enhanced erector spinae muscle activity under motion. The authors concluded that lifting tasks in a moving environment could induce a greater risk for injuries due to manual material handling related overexertion, particularly over extended time periods [11].

LOWER BACK IMPAIRMENTS IN MARITIME WORKERS

MERCHANT SEAFARERS

Regarding musculoskeletal disorders among seafarers in merchant shipping, two studies were identified; one retrospective cohort study [17] and one cross-sectional survey [18].

Abaya, Enriquez [17] set up a study cohort of 33,616 Filipino seafarers that were checked in a pre-employment medical exam (PEME). One subgroup additionally underwent a pre-employment functional capacity evaluation (FCE, n = 5,578), which particularly evaluates physical capabilities and body kinetics. Additionally, it imparts correct lifting techniques. The other subgroup was employed after completing the PEME only (n = 28,038). The number of seafarers that had to be repatriated due to "lumbar pain, lower back pain, lumbago, herniated lumbar disc, or L4-L5 disc herniation or injury" was lower in the FCE group (odds ratio 0.346).

Geving, Jorgensen [18] examined the physical activity level among 577 seafarers of a Norwegian shipping company in a cross-sectional survey. About 28% reported to have been troubled by lower back pain. Interestingly, only 39% of the investigated subjects claimed to exercise two or more times a week on board the ship, compared to 70% exercising during home leave. The authors concluded that on-board exercise facilities should be provided more frequently and arranged more attractively. It is consistent in both studies, that frequent physical exercises seem to be an important aspect for a healthy musculoskeletal system in merchant seafarers.

FISHERMEN

Within the observation period, seven studies were found regarding musculoskeletal diseases among fishermen. These were cross-sectional surveys [n = 412, 19–21], field studies [n = 122] or retrospective cohort studies [n = 223, 24].

Berg-Beckhoff, Østergaard [12] observed in their study that 80% of 270 Danish fishermen claimed to have had lower back pain in the year prior to the survey, of which 37% lasted for at least 30 days during the last year. In that study, low, medium and high workload was estimated according to a score system based on a questionnaire focusing on the frequency of different tasks. Compared to low workload, a medium workload increased the incidence of lower back pain by 32% and by 60% at a high workload, respectively.

Dienye, Birabi [19] conducted a cross-sectional study including 384 Nigerian fishermen of which 68.2% reported lower back pain (LBP). Severe LBP was mostly associated with marriage (79.5%; without LBP 63.1%), abnormal BMI (73.3%; without LBP 7.1%) and lower education (45.5%; without LBP 15.6%).

Fishermen with at least 21 years of seafaring experience reported the lowest rate LBP. A survey by Percin, Akyol [20] among 1,166 Turkish small-scale fishermen revealed that 84% suffered from diseases of the musculoskeletal system and connective tissue. These were often located in the lower back.

Kaerlev, Jensen [23] investigated the musculoskeletal health in a cohort study within the population of all Danish seafarers (differed in officers and non-officers) and fishermen between 1994 and 1999 with a minimum of six months of experience at sea. They compared health data of more than 20,000 seafarers and fishermen to the general Danish population and calculated standardized incidence ratios (SIR). The SIR for injuries (single body region) was increased for non-officers (109, 95% CI: 105–114) and fishermen (140, 95% CI: 134–146) compared to land-based population. Interestingly, fishermen — compared to officers and non-officers — also had an increased SIR (124, 95% CI: 116–132) for musculoskeletal diseases, especially thoraco-lumbar disc disorders (185, 95% CI: 160–215). Officers had relatively low SIRs (< 100) in almost every examined category of musculoskeletal diseases, compared to non-officers and fishermen.

The latter is consistent to data generated in a field study by Mirka, Shin [22]. The authors used the continuous assessment of lower back stress (CABS) method on two- or three-men crab fishing crews. They measured high inter- and intra-crew variability: The captain of the ship experienced a lower amount of physical stress during the workday, whereas the mate and third man had to pull heavy loads aboard and staid in awkward trunk positions for more than five minutes.

These findings line up with results of a retrospective cohort study with 116 fishermen [24], who also claimed that rather certain activities on board of fishing ships are associated with higher incidence of lower back pain. Amongst other, they named forces greater than 20 lbs. while in a non-neutral trunk position and spine compression greater than 3,400 N. Complementary data is found in a study by Thamrin, Pasinringi [21]. This cross-sectional survey with 56 fishermen analyzed relations of body mass index (BMI) and work posture to musculoskeletal disorders using the Nordic Body Map and Rapid Entire Body Assessment

questionnaire. While there is no significant relation between BMI and musculoskeletal disorders ($p = 0.848$), the authors found a significant relation to work posture [$p < 0.001$; 21].

MARITIME SEAFARERS AND FISHERMEN

Figure 3 illustrates data of the four cohort studies, which comprise prevalence of LBP both from seafarers (Geving et al., 2007) and fishermen (Kucera et al., 2009; Berg-Beckhoff et al., 2016; Dienye et al., 2016) and compared them with the findings of a study on a male German land-based population [12, 18, 19, 24, 25]. All studies on fishermen depict higher prevalence on LBP than the land-based population, while the study concerning seafarers had lower prevalence. Thus, fishermen seem to be at higher risk for lower back impairments than seafarers.

DISCUSSION

In this review the recent scientific knowledge about the impact of the shipboard work environment on the lower back and related health consequences for maritime workers was summarized. Different study types with various foci have contributed information.

SHIP MOTIONS AND WORK STRAIN

Some of the included studies imply that especially vertical ship motions (along z-axis) can increase physical stress [6, 7, 11]. Thus, external circumstances, such as weather and area of operation should be taken into consideration in further studies to evaluate the maritime workers' spinal strain on the high seas. Vertical acceleration is also dependent to the type and size of a vessel. Smaller vessels are usually more susceptible to sea conditions. Within a vessel acceleration increases with distance to turning axes. That means, e.g., that employees working on a high bridge are more exposed to vertical movement, than employees working in an engine room. On large ships, therefore, vertical acceleration depends on the location on board. However, Walter, Wagman [10] describes compensation efforts of the musculoskeletal system that may increase the overall muscle activity and may also have positive, training-like effects on the seafarer's strength and health. This is especially true when seafarers are only exposed to ship movements without simultaneous heavy lifting tasks. Therefore, it is important to compare groups which differ in heaviness of work tasks.

LBP IN COMPARISON OF SEAFARERS AND FISHERMEN

Compared to seafarers, fishermen perform heavy work tasks on the high seas more frequently and are therefore rather prone to lower back strain. Latter assumption is consistent with results from Kaerlev, Jensen [23] and findings of Oldenburg, Harth [26 and b] comparing the Standardized Hospitalization Risk (SHR) of maritime workers with that of the general population. Concerning musculoskeletal or connective tissue diseases, the authors observed lower SHR for seafarers (0.91, 95% CI 88–93), but increased SHR for fishermen (1.08, 95% CI 0.99–1.19). In total, fishermen seem to be at higher risk for lower back impairments than seafarers. Correspondingly, Thamrin, Pasinringi [27] found an association between musculoskeletal disorders and duration of working period of fishermen.

Comparing this risk for LBP, it also needs to be considered, that the size of fishing vessels on which most fishermen were working in the analyzed publications, is in general much smaller than most cargo or passenger vessels. Therefore, the impact of ships' motion on fishermen is usually higher due to higher z-axis acceleration. However, the actual size of vessels the maritime workers were working on was often not stated in the reviewed studies.

LBP IN COMPARISON OF OCCUPATIONS ON BOARD

As outlined by Mirka, Shin [22], there are also notable differences in physical workload and musculoskeletal strain between crew members of a single ship. The occupational tasks (e.g., heavy lifting) as well as the function on board can impact the risk for lower back complaints. The workplace on the ship plays another role especially on larger vessels. In several studies engineers and nautical officers are usually both categorized as officers. The usual workplace during sea voyages for nautical officers is the ships' bridge, which is more distant to x and y axes of the ship compared to the engine control room. Thus, it is assumed that nautical officers are exposed to stronger vertical ship motions. Despite this, nautical officers normally do not perform physically heavy tasks on bridge. Due to the merge of bridge and engine control room staff, the analyzed studies are not able to examine whether the working area affects the abundance of lower back impairments. Possibly, the diverse maritime professions each attract employees out of different social- or economic groups, which leads to a generally altered health state among the maritime workers: A study by Morken, Magerøy [28] concluded that a physically active lifestyle, both at workplace and at home, is associated with a lower incidence of musculoskeletal disorders in Norwegian navy workers.

It is further assumed, that particular activities on board seem to negatively influence the seafarer's musculoskeletal health rather than the ships movement itself. This is supported by the significant association between bad working postures and musculoskeletal disorders of fishermen [21].

Studies by Hansen, Tüchsen [14], Kaerlev, Jensen [23] and Oldenburg, Harth [13] indicated decreased rates for musculoskeletal diseases among seafarers compared to general population. This leads to the hypothesis that working

in a moving environment may even have positive effects on the lower back musculoskeletal system. The positive effect, however, only seems to apply, if the subject is not simultaneously exposed to high levels of physical work at sea such as fishermen [26].

LIMITATIONS

Although most of the included studies consensually highlighted lower back complaints as a central health problem among maritime workers, the examined populations and the shipboard circumstances are subjected to a high degree of variation and bias. While some studies are based on extremely small and homogenous populations, others do not further outline work circumstances and cultural or health background of the crew. According to the results of Abaya, Enriquez [17] it seems noticeable that the seafarer's pre-employment physical capacity influence the risk for lower back injuries during their work on ships. When studying the maritime workers' spinal strain, it may be too simple to just classify populations according to their profession.

In most studies there is also only little information about the amount of systematic prevention of injury in the wide field of maritime occupations (dependent on, e.g., national work safety laws, cultural background, working hours etc.). Further investigations should regard the fact, that knowledge about correct lifting techniques can likely prevent injuries [17, 29]. Studies with back injuries connected to accidents were not included. However, there is a relatively high risk for such accidents on vessels. These injuries may increase risks for other non-accident-related back injuries.

Putting all these facts together, it becomes obvious that maritime work is very heterogeneous and the risk for lower back impairments among maritime workers needs to be evaluated in a differentiated manner. Numerous factors influenced and biased the results in previous studies. Therefore, data from only small heterogenous collectives in isolated working conditions cannot completely depict the complex working situation in seafaring. Further investigations should either include very large groups of maritime workers in national/international cohorts or improve existing biomechanical models, to assess and calculate individual spinal health risks when working on board a ship in certain circumstances.

CONCLUSION

There are many different maritime professions and occupations, which are subjected to high physical workload. A ship itself poses a challenging work environment due to various factors (ship movements, narrow aisles and ceiling, bulkheads, slippery surfaces etc.). Numerous studies have identified a higher prevalence for lower back pain in fishermen compared to both land-based working populations and other maritime professions.

However, maritime employees with lower workload, such as officers, do not show higher prevalence or even increased hospitalization rates for lower back pain. Field studies displayed increased physical stress during heavy working tasks at sea due to the ship motion.

Reviewing the recent scientific publications may thus lead to the conclusion, that a moving environment could generally also have positive effects on the workers' health if heavy physical work is not performed simultaneously. In such a case, the negative effects of the physical stress may be intensified if the ship is moving. Additional longitudinal evaluations and further field studies with larger populations and improved biomechanical modeling are required to verify this hypothesis.

As in most physically challenging jobs with repetitive activities, consequent prevention measures might be a key to lower the morbidity. Therefore, special attention to work and job-related aspects is required.

ARTICLE INFORMATION AND DECLARATIONS

Author contributions: LB, PF, VH and MO gave substantial contributions to the conception or design of the manuscript, or the interpretation of data. PF wrote a first version of the manuscript, which was then restructured and extended by LB who also created figures. PF, LB and MO were involved in drafting the work or revising it critically for important intellectual content. All authors gave their final approval of the version published.

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