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# Epidemiological Analysis of the Most Relevant Diseases Among Sailing Seafarers

By


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Supervisor: **Prof. Francesco Amenta**

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**Declaration**

I hereby declare that this PhD dissertation is my own original work that I conducted during my doctoral journey period (2020 – 2023), and that it has not been submitted, in whole or in part, in any previous application for a degree. I have indicated and acknowledged all the sources (published or unpublished) that I have used quotes where required and have cited their sources in the references section.

Marzio Di Canio

Signature

Date

15/April/2024

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## Abstract

Seafaring has historically been considered a high-risk occupation due to a combination of factors, including lifestyle-related diseases, stress, and fatigue that are inherent to life at sea. The maritime industry can be highly stressful for seafarers. They often work in a confined and isolated environment, away from their families and support networks for extended periods. The objective Introduce time-motion analysis for assessing the impact of workplace load on duty activity in seafaring. Examine internal fatigue load. Examine postural workload. The aims of the research will be achieved through surveys, analysis of existing databases and field research. The methods involved: A review of the existing literature, Epidemiological analysis of musculoskeletal systems diseases among seafarers, Epidemiological analysis of cardiovascular diseases among seafarers. Instrument recordings of physical demands of seafaring. Instrument recordings of Postural workload. The aims of the research will be achieved through surveys, analysis of existing databases and field research. The methods involved: A review of the existing literature, Epidemiological analysis of musculoskeletal systems diseases among seafarers, Epidemiological analysis of cardiovascular diseases among seafarers. Key discoveries include disparities in CVD diagnosis between officers and non-officers, with age being a significant risk factor, and a positive correlation between body mass index (BMI) and blood pressure. Additionally, a risk prediction model for hypertension was developed, aiding in early identification of high-risk individuals. Recommendations emphasize early diagnosis, regular health monitoring, and crew training in basic life support. The analysis of time spent in high and low-intensity work activities revealed variations among ranks, with physical and psychosocial stressors significantly impacting seafarers' well-being. Posture assessment highlighted differences among ranks, with non-officers showing similarities with other at-risk workers like nurses. These findings underscore the need for targeted prevention strategies, improved workplace organization, and enhanced job variety to mitigate health risks among seafarers.

List of articles published and submitted during my PhD studies.

I have published 14 documents as a first, corresponding author, and co-author during my PhD studies. My research experiences are primarily focused on distribution, patterns and determinants of health and disease conditions in seafarers.

**Published articles:**

1. SAGARO, Getu Gamo, et al. Self-reported diabetes mellitus among seafarers: **occupational and sociodemographic predictors**. International Maritime Health, 2024, 75.1: 19-28.

2. *SAGARO, Getu Gamo, et al.* ***Risk prediction model of self-reported hypertension for telemedicine based on the sociodemographic, occupational and health-related characteristics of seafarers: a cross-sectional epidemiological study****. BMJ open, 2023, 13.10: e070146.*

3. *Di Canio M, Burzi L, Ribero S, Amenta F, Quaglino P.* ***Role of teledermatology in the management of dermatological diseases among marine workers: A cross-sectional study comparing general practitioners and dermatological diagnoses.*** *Front Med (Lausanne). 2022 Aug 12;9:955311. doi: 10.3389/fmed.2022.955311. PMID: 36035410; PMCID: PMC9412975.*

4. *SAGARO, Getu Gamo, et al****. Occupational Diseases and Injuries on Board Ships: A Preliminary Analysis for an Epidemiological Observatory of Seafarers****. In: Medical Sciences Forum. MDPI, 2022. p. 7.*

5. *Amenta, F., Di Canio, M., Arcese, A., Bajani, F., Ruocco, C., & Sibilio, F.* ***Advanced Telemedicine Solutions for High-Quality Medical Assistance at Sea.*** *In: Medical Sciences Forum. MDPI, 2022. p. 9.*

6. *Chintalapudi N, Angeloni U, Battineni G, di Canio M, Marotta C, Rezza G, Sagaro GG, Silenzi A, Amenta F.* ***LASSO Regression Modeling on Prediction of Medical Terms among Seafarers' Health Documents Using Tidy Text Mining****. Bioengineering (Basel). 2022 Mar 17;9(3):124. doi: 10.3390/bioengineering9030124. PMID: 35324813; PMCID: PMC8945331.*

7. *Sagaro, Getu Gamo, et al.* ***"Incidence of occupational injuries and diseases among seafarers: A descriptive epidemiological study based on contacts from onboard ships to the Italian Telemedical Maritime Assistance Service in Rome, Italy."*** *BMJ open 11.3 (2021): e044633.*

8. *Sagaro GG, Battineni G, Di Canio M, Amenta F.* ***Self-Reported Modifiable Risk Factors of Cardiovascular Disease among Seafarers: A Cross-Sectional Study of Prevalence and***

*__Clustering__. J Pers Med. 2021 Jun 4;11(6):512. doi: 10.3390/jpm11060512. PMID: 34199824; PMCID: PMC8227251.*

9. *Sagaro GG, Di Canio M, Talevi E, Amenta F. __Telemedicine for Pre-Employment Medical Examinations and Follow-Up Visits on Board Ships: A Narrative Review on the Feasibility. Healthcare (Basel).__ 2021 Jan 13;9(1):69. doi: 10.3390/healthcare9010069. PMID: 33451120; PMCID: PMC7828583.*

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12. *Battineni G, Sagaro GG, Chintalapudi N, Di Canio M, Amenta F. __Assessment of Awareness and Knowledge on Novel Coronavirus (COVID-19) Pandemic among Seafarers.__ Healthcare (Basel). 2021 Jan 25;9(2):120. doi: 10.3390/healthcare9020120. PMID: 33503921; PMCID: PMC7912131.*

13. *Sossai P, Uguccioni S, Mela GS, DiCanio M, Amenta F__. Coronavirus variant COVID-19 pandemic: a report to seafarers.__ Int Marit Health. 2020;71(3):191-194. doi: 10.5603/IMH.2020.0034. PMID: 33001431.*

14. *Sagaro GG, Battineni G, Chintalapudi N, Di Canio M, Amenta F__. Telemedical assistance at sea in the time of COVID-19 pandemic.__ Int Marit Health. 2020;71(4):229-236. doi: 10.5603/IMH.2020.0041. PMID: 33394487.*

**Under review articles:**

1. *Battineni, G. , Arcese, A., Chintalapudi, N., Dicanio, & Amenta, F. (2024). __Approaches to medical emergencies on commercial flights__. Emergency Medicine.*

2. *Battineni, G. , Dicanio, & Amenta, F. (2024). __Physical Activity and Sedentary Behavior Among Seafarers__. Int Marit Health.*

## Introduction

Shipping is the backbone of the global economy and trade. Currently, shipping constitutes one of the most widely used transportation systems, accounting for over 80% of global trade (International Maritime Organization, 2019). Shipping is a crucial component of the logistics and supply chain. It connects manufacturers, suppliers, and consumers across different countries, allowing for the transportation of raw materials, finished products, and consumer goods. (Center for Maritime Safety and Health Studies, 2019). Over 1.6 million seafarers are employed by deep-sea merchant vessels worldwide (Manpower Report-The global supply and demand for seafarers, 2015). These seafarers play essential roles in operating and maintaining deep-sea merchant vessels. They include a wide range of professionals, from captains and officers to engineers and deckhands, who ensure the safety and efficiency (Eva Grey, 2019).

However, workers at sea are more likely to die, be injured, or be ill than their counterparts ashore due to the exceptionally hazardous working conditions (Center for Maritime Safety and Health Studies, 2019), which include:

**Physical and Psychological Strain**: Working on a ship often involves physically demanding tasks, such as heavy lifting, long working hours, and exposure to harsh weather conditions. These physical strains can lead to injuries, fatigue, and musculoskeletal problems. Additionally, the isolation and confinement of a ship can lead to psychological stress and mental health issues among seafarers (Carotenuto, 2013).

**Sudden Climate Changes**: Seafarers are exposed to a wide range of weather conditions and climate changes as they travel across different regions and seasons. Sudden and extreme weather events, such as storms and rough seas, can pose significant risks to both the vessel and the crew, potentially leading to accidents and injuries (Rengamani, 2012).

**Environmental Factors:** Seafarers are exposed to various environmental factors that can affect their health. This includes exposure to electromagnetic radiation from onboard equipment, vibration from the ship's machinery, and sound radiation, all of which can have adverse health effects over time (Yang, 2023).

**Limited Access to Healthcare**: While onboard medical facilities have improved, they may not always be equipped to handle serious medical conditions. Seafarers often face limited access to medical care when they're at sea, which can exacerbate the impact of injuries or illnesses (Nittari, 2019).

**Accidents and Hazards**: The maritime industry also has specific hazards like navigating through congested and sometimes dangerous waters, handling heavy cargo, and operating machinery in challenging conditions. These factors can increase the risk of accidents and injuries (Saguaro, 2021).

**Long Working Hours and Fatigue**: The shipping industry often requires seafarers to work long hours with irregular schedules. This can lead to fatigue, which is a significant risk factor for accidents and decreased cognitive and physical performance (Allen, 2008).

**Infectious Diseases and Health Risks**: The confined living conditions on a ship can facilitate the spread of infectious diseases, which was particularly highlighted during the COVID-19 pandemic. Electromagnetic, vibration, and sound radiation, which are all factors contributing to the higher mortality, injury, and illness rates of seafarers (Pallotta, 2019).

Statistics from studies conducted in the British and Danish maritime industries reveal the significant disparities in death rates between seafarers and workers in other sectors: death rate for seafarers working on board British merchant ships was 23.9 times higher than the death rate for all British workers (Roberts, 2002). A study involving Danish workers at sea during 1986-1993 found that the mortality rate for Danish seafarers at sea was 11.5 times higher than the mortality rate for Danish workers who were not engaged in maritime work (H. L. Hansen, 1996).

Seafaring has historically been considered a high-risk occupation due to a combination of factors, including lifestyle-related diseases, stress, and fatigue that are inherent to life at sea. The maritime industry can be highly stressful for seafarers. They often work in a confined and isolated environment, away from their families and support networks for extended periods. The stressors can include the pressure of navigating a vessel, unpredictable weather conditions, and the responsibility of ensuring the safety of the crew and cargo. The psychological strain can lead to mental health issues like anxiety and depression (Carotenuto, 2012; Allen, 2008).

According to previous research, fatigue plays a significant role in certain areas of the maritime industry. A recent survey of 79 crew members on six ships in 2003 revealed concerning statistics. More than 40% of participants reported working over 80 hours a week, which is well above recommended limits for work hours. Additionally, over 60% of these crew members did not get sufficient rest. This emphasizes the long working hours and inadequate rest periods that many seafarers experience (Grech, 2003).

According to Gander (2005), 61% of deck officers reported feeling often affected by fatigue when they were on duty during their work. This indicates that a significant majority of deck officers experienced fatigue-related issues while on duty. Autor also found that 26% of the sample of ferries (presumably referring to ferry vessels) had been involved in incidents related to fatigue in the previous 6 months. This suggests that a notable portion of ferry-related incidents could be attributed to fatigue (Gander, 2005). It's important to note that these findings highlight the potential impact of fatigue on the performance and safety of deck officers and the maritime industry. Fatigue can impair decision-making, reaction times, and overall cognitive and physical performance, which is especially concerning in safety-critical roles such as those of deck officers on ships and ferries (International Maritime Organization, London, 2019).

Published studies suggest that there is an upper limit for the tolerance of mixed physical work over an 8-hour workday. This limit is described as one-third of a person's maximal aerobic capacity. In other words, individuals should not engage in mixed physical work that exceeds this limit over an 8-hour period to avoid potential health risks and fatigue. (Harrington, 2001). Heavy physical work can be a potential risk factor for different diseases, including cardiovascular and musculoskeletal system diseases. These types of diseases are often linked to physical stress and strain on the body. (Virkkunen, 2007; Leino, 1989). Prolonged or excessive physical stress, especially in situations where an individual exceeds their physical capacity, can have a range of effects on the cardiovascular system. Physical stress, such as heavy physical work or strenuous exercise, can lead to an elevated heart rate, increasing blood pressure to ensure that the body's organs and muscles receive adequate oxygen and nutrients, and can contribute to the development of cardiovascular diseases (CVD) (Kivimäki, 2002). The term "cardiovascular diseases" (CVD) include a wide range of ailments that affect the circulatory system. These diseases primarily involve the heart, blood vessels, and the circulation of blood throughout the body. Some of the major cardiovascular diseases included in this category, as defined by the World Health Organization (WHO) in 2016, are: cerebrovascular disease, peripheral arterial disease, rheumatic and congenital heart diseases, and venous thromboembolism.

Cardiovascular diseases (CVD) represent a significant and concerning health issue among seafarers, contributing to a high death rate and illness at sea. The unique working conditions and lifestyle challenges faced by seafaring personnel can make them more vulnerable to cardiovascular problems. According to Roberts (2010), a significant majority of documented mortalities at sea were attributed to cardiovascular diseases. Oldenburg (2014) conducted a survey involving 465 nautical officers to gain insights into the occurrence of diseases and accidents on board ships, which necessitated emergency actions like port calls, course deviations, or evacuations. The survey revealed that CVD ranked as the second most frequent cause for serious medical emergencies on board ships (Oldenburg, 2014). It is evident that CVD is a major health concern among seafarers, and it has been a leading cause of work-related mortality for several decades. Studies have consistently shown a high incidence of CVD among maritime workers. The prevalence of CVD has increased over the years, with a notable shift from less than 15% in the 1920s to 45% in the 1950s (Roberts, 2010). Lefkowitz (2015) highlight the significant impact of cardiovascular diseases on seafarers in terms of their ability to work effectively on ships and their tendency to return home prematurely. In fact, cardiovascular diseases are the primary cause of seafarer unfitness (inability to work) on ships (Lefkowitz, 2015) and are also important contributors to seafarers returning home (Lefkowitz, 2015). Some studies indicate that there are differences in CVD risk based on the rank of seafarers. Non-officers, which includes deck crew, engine crew, and galley staff, appear to be at a higher risk of developing cardiovascular diseases compared to officers, such as deck officers, engine officers, and captains (Sagaro, 2021). Furthermore, several prevalent risk factors for CVD among seafarers have been identified:

- Tobacco Smoking (Hansen, 1994): Smoking is a known risk factor for CVD, and its prevalence among seafarers is noteworthy.
- Hazardous Alcohol Consumption (Kirkutis, 2004): Excessive alcohol consumption can increase the risk of CVD and is another common risk factor among maritime workers.
- Inactivity (Youn, 2020): Physical inactivity is a significant risk factor for CVD, and it appears to be a prevalent issue among seafarers who may have limited opportunities for exercise while at sea.
- Unhealthy Diet (Oldenburg, 2013): Poor dietary choices can contribute to CVD risk. The unhealthy diet is another risk factor commonly observed in this group.
- Overweight and Obesity (Szafran-Dobrowolska, 2019): Seafarers are more likely to be overweight and obese than the general population. Overweight and obesity are established risk factors for CVD.
- Isolation from Family (Carotenuto, 2012): Seafarers often spend extended periods of time away from their families and loved ones. This isolation can lead to emotional and psychological stress, which can, in turn, impact cardiovascular health.

In the past, healthcare onboard vessels were primarily the responsibility of the ship's captain, whose training in medicine and hygiene may have been rudimentary at best. This lack of medical expertise presented significant challenges in providing adequate healthcare for seafarers. he development of radio communication in the 1920s marked a significant advancement in maritime healthcare. It enabled doctors on land to diagnose and provide medical advice to patients on ships, especially in cases of cardiac emergencies. This improved the ability to address medical issues while at sea. In cases where medical conditions required more advanced care or intervention, doctors could recommend medical evacuation (MEDEVAC) or diverting the ship to bring the patient ashore for treatment. These actions helped provide access to more comprehensive medical services (World Health Organization, 2016). Telemedical Maritime Assistance Services (TMAS) centers have become essential in providing medical advice and assistance to seafarers. However, it's important to note that the healthcare services in the maritime environment differ from those available onshore. Several challenges and limitations exist:

- Lack of Medical Skills: Ship officers responsible for providing medical care onboard may have limited medical training, which can affect the quality of care they can provide (Horneland, 2009).
- Limited Medical Equipment and Supplies: Ships may have limited availability of medical equipment and supplies, which can restrict the scope of medical interventions (Horneland, 2009).
- Supply Constraints: There may be constraints on the availability of medical products and medications onboard, limiting the treatment options for sudden diseases or emergencies (Horneland, 2009).

Maritime work is dangerous, the health risks extend beyond cardiovascular disease. One significant health concern among seafarers is musculoskeletal problems, with low back pain (LBP) being a prominent issue. Low back pain is highly prevalent, with most people experiencing it at some point in their lives. It can be acute, lasting for a short duration, or become a chronic condition lasting for months or even years. LBP can result from a wide range of causes, including muscle strains, ligament sprains, herniated discs, spinal stenosis, osteoarthritis, and more. Sometimes, the cause may not be immediately apparent. In some cases, LBP can become a chronic and complex condition. It may be associated with various factors, such as lifestyle, work-related issues, psychological factors like stress, and underlying medical conditions. Identifying the exact cause of LBP can be elusive. It often requires a comprehensive evaluation, which may include imaging tests like X-rays or MRIs, as well as a thorough medical history and physical examination. Managing LBP can also be elusive because what works for one person may not work for another. Treatment options range from rest, physical therapy, and medications to more invasive interventions like injections or surgery. Personalized treatment plans are often necessary (WHO, 2003). Low back pain (LBP) is a common issue for maritime workers, particularly those in jobs that involve physically demanding and repetitive tasks. Here are some factors that can contribute to low back pain among maritime workers (Jepsen, 2017; Jepsen, 2015; Lefkowitz, 2015; Jensen, 2014):

- Heavy Lifting: Many maritime jobs require lifting heavy objects, whether it's cargo, equipment, or supplies. Improper lifting techniques or inadequate training can lead to back strain and injury.
- Awkward Postures: Maritime workers may need to work in confined spaces or assume awkward postures when performing tasks, which can put stress on the lower back.
- Vibration and Shock: Workers on vessels are exposed to constant vibrations and shocks from the machinery and the sea. This continuous jarring of the spine can lead to back pain over time.
- Repetitive Movements: Tasks like hauling nets, securing lines, or operating machinery often involve repetitive bending, twisting, or lifting, which can strain the lower back.
- Long Hours: Maritime workers often work long hours, which can lead to fatigue and increased risk of injury due to reduced concentration and muscle fatigue.
- Environmental Factors: Harsh weather conditions and the constantly shifting deck of a ship can make it challenging to maintain proper posture and balance, increasing the risk of falls and injuries.

An analysis of the trends in pathologies assisted by the Centro Internazionale Radio Medico (C.I.R.M.) over the years has shown that the locomotor system pathologies are a common problem on board ships, as indicated by Mahdi in 2016. Low back pain is particularly noteworthy in this context and is a significant contributor to the overall burden of musculoskeletal conditions, as highlighted by Cieza in 2021. Maritime workers, including seafarers and offshore personnel, often perform physically demanding tasks, are exposed to challenging environmental conditions, and may work in confined spaces, which can increase the risk of developing musculoskeletal issues, especially in the lower back (Cieza, 2021). Musculoskeletal conditions, including low back pain, neck pain, fractures, osteoarthritis, amputation, and rheumatoid arthritis, represent a significant global health concern. An estimated 1.71 billion people worldwide are affected by musculoskeletal conditions. This high number underscores the global significance of these health issues (Cieza, 2021). The prevalence of musculoskeletal conditions is not uniform across the world. High-income countries, often with better healthcare systems and living conditions, report a significant burden, affecting 441 million people. The Western Pacific region follows closely with 427 million affected individuals, and Southern Asia has 369 million people grappling with these conditions. These regional differences can be attributed to various factors, including healthcare access, lifestyle, and genetics (Cieza, 2021). It's well-documented that seafarers frequently experience musculoskeletal disorders, and this issue is prevalent across different countries in the maritime industry. Several studies have contributed to our understanding of the challenges faced by seafarers in this regard, despite variations in working conditions (Jensen OC, 2003; Jaremin B, 1997; Jensen OC, 1996). Study suggest that the physical demands of fishing can lead to a range of health problems, including musculoskeletal issues. Lipscomb (2004), found that 38.5% of fishermen interviewed in interviewed in his study reported musculoskeletal symptoms. The most common types of symptoms included low back pain (17.7%), hand pain (7%), wrist pain (7%), and shoulder pain (7%) (Lipscomb HJ, 2004). A study conducted on 39 Danish fishermen found that rotator cuff syndrome and carpal tunnel syndrome were common on board, these issues were particularly prevalent among older fishermen (Esbjerg, 2005). Authors suggest that the risk of developing such musculoskeletal problems may increase with age or with prolonged exposure to the physical demands of fishing. Fishermen report repetitive hyper flexing and twisting movements of the wrists (Tanaka, 1997). The constant flexing and twisting of the wrists can put pressure on the median nerve, leading to carpal tunnel syndrome (Tanaka, 1997). Repetitive movements can lead to overuse injuries in the wrist and forearm, such as strains and sprains (Tanaka, 1997). Fishermen do indeed have a higher risk of traumatic injuries to the shoulder and wrist due to the nature of their work, which often involves heavy lifting, repetitive movements, exposure to adverse weather conditions, and potentially hazardous equipment. (Videman, 2007; Lau, 2000).

**Research objectives**

Work-related diseases are illnesses that arise from exposure to risk factors in the workplace. Understanding work-related diseases is essential for several reasons that can contribute to the overall health, safety, and productivity of workers and the economic stability of organizations and societies. Here are key points emphasizing its importance:

**Prevention and Early Intervention**: Recognizing the causes and early signs of work-related diseases allows for timely preventive measures and interventions, reducing the severity and impact on workers' health.

**Improved Quality of Life:** By understanding these diseases, employers and health professionals can implement strategies that enhance workers' well-being and quality of life.

**Reduced Healthcare Costs**: Preventing and managing work-related diseases can lead to significant savings in healthcare expenses for both employers and employees.

**Risk Assessment:** Understanding the relationship between work and disease helps in identifying and assessing workplace hazards and risks.

**Tailored Interventions:** Enables the development of specific interventions and safety protocols tailored to particular industries and job roles.

Work demand refers to the physical, mental, and emotional requirements placed on an individual by their job. It encompasses various aspects of the job that require effort and can influence an employee's well-being, productivity, and overall job satisfaction. Physical demands include activities requiring physical effort such as lifting, carrying, pushing, or pulling heavy objects. It also involves repetitive movements that can lead to musculoskeletal disorders and specific postures that can cause strain, like standing or sitting for long periods or assuming awkward positions. Workload and time pressure refer to the volume of work to be completed within a specific timeframe, the constraints imposed by deadlines, and extended work hours beyond the standard workday, which can lead to fatigue and stress. Understanding work demand is crucial in the context of seafarers for several reasons, as the maritime industry is unique and poses specific challenges:

**Safety**: The maritime environment can be harsh and unforgiving. Understanding work demand is essential to ensure that seafarers can operate safely under various conditions, including rough seas, adverse weather, and remote locations.

**Health and Well-Being**: Seafarers often work long hours with irregular schedules, which can lead to fatigue and stress. By understanding work demand, employers and regulatory bodies can implement measures to protect the physical and mental health of seafarers.

**Crew Retention**: High levels of stress and fatigue can lead to high turnover rates in the maritime industry. Understanding work demand can help employers implement strategies to retain experienced seafarers, which is essential for the safe operation of vessels.

**Compliance with Regulations**: There are international regulations, such as the Maritime Labour Convention (MLC) and the International Labour Organization (ILO) standards, that set guidelines for work and rest hours for seafarers. Understanding work demand is critical to ensure compliance with these regulations.

**Risk Management:** A thorough understanding of work demand allows for effective risk management. This includes identifying potential hazards, evaluating their impact on safety and performance, and implementing measures to mitigate those risks.

**Training and Skill Development**: The nature of work on ships requires seafarers to have specific skills and competencies. Understanding work demand helps in designing appropriate training programs to equip seafarers with the necessary skills to perform their duties safely and efficiently.

**Workload Management**: Properly understanding work demand enables the allocation of workloads that are reasonable and achievable. Overburdening seafarers can lead to reduced performance and increased risk of accidents.

**Emergency Response**: In emergency situations, seafarers need to be able to respond quickly and effectively. An understanding of work demand helps in preparing seafarers for these situations and ensuring they can react efficiently under stress.

**Cultural and Societal Factors:** Understanding work demand includes considering cultural and societal factors that may impact seafarers' well-being and work performance, as many seafarers come from diverse backgrounds and may have different needs and expectations. Quantifying the physical demands of seafaring involves assessing various factors related to the physical work and activities that crew members perform while at sea. Time-motion analysis can be a valuable method to quantify the physical work and activities involved in various tasks or jobs. Time-motion analysis, also known as time and motion study, is a systematic technique used to analyze and improve work processes and task efficiency. It is a method widely used in various industries to understand how time is allocated to different tasks, identify inefficiencies, and streamline workflows.

Time-motion analysis includes analyzing movement and the time spent on each movement through video analysis. This method is very powerful, since the investigator can analyze every second spent by each worker during every work shift. Time-motion analysis combined with physiologic data can be valuable in assessing the physiologic demand during work duty (Meade, 2016). There are three discrete aims of this study. These are to:

**1.** Introduce time-motion analysis for assessing the impact of workplace load on duty activity in seafaring
**2.** Examine internal fatigue load: time spent by seafarer in low intensity activity during work (e.g. watching monitor in sitting position); time spent by seafarer in high intensity activity during work (e.g. move heavy loads); number of working hours.
**3.** Examine postural workload, it includes shoulder position, knee interspace, ankle position, and overall symmetry of the body during work duties.

The aims of the research will be achieved through surveys, analysis of existing databases and field research. The methods involved:

1. A review of the existing literature
2. Epidemiological analysis of cardiovascular diseases among seafarers
3. Epidemiological analysis of musculoskeletal systems diseases among seafarers
4. A questionnaire survey of working and rest hours, physical workload and physical work-activity performed on board.
5. Instrument recordings of physical demands of seafaring: to quantify seafaring physical demands of all the physical aspects of seafarer's work from merchant ships will be recorder. In order to asses internal fatigue load analysis of activities for the seafarer will carry out considering the following categories: *Low-intensity work activities (LIWA):* it includes

working in a managerial or supervisory capacity, performing inventory; ordering supplies; organization of supplies or records; workplace inspections; answering the phones; working in sitting position; typing and filing reports; write; pinch; walk; remaining in a seated position; remaining in upright position; seizing, grasping, holding, turning, or otherwise working with the hands; *High-intensity work activities (HIWA):* moving an object from one level to another; transporting an object over a distance, usually holding in the hands, or on the arm(s) or shoulder(s); transporting an object over a distance, usually holding in the hands, or on the arm(s) or shoulder(s); exerting force upon an object in order to move the object away from worker; exerting force upon an object in order to move the object towards worker; kneel; crouch/squat.

6. Instrument recordings of Postural workload: the prevention of musculoskeletal disease involves the analysis of the work posture to determine the risk factors and apply a series of preventive measures. Bad postures for the back, arms and legs, repetitive movements and the weight of the load handled will be analyzed by a multidisciplinary approach, ranging from video recording, computer programs (I.E. Kinovea®), and posture assessment system (UNI ISO 11226) (Gómez-Galán, 2016).

Seafarer will group in 5 macro-categories: “Deck Officers” (include: Deck Cadet, Third Mate, Second Mate, Chief Mate, Master); “Deck Crew” (include: Boatswain, Able Seaman, Ordinary Seaman); “Engine Officers” (include: Chief Engineer, Second Engineer, Third Engineer, Fourth Engineer); “Engine Crew” (include: Motorman, Oiler, Wiper,); “Galley Staff” (include: Cook, Steward).

Over the past years, several studies have advanced our knowledge of the consequences of job demands for seafarers’ well-being (Oldenburg, 2019; Jepsen, 2015). Effects of work and rest hours on fatigue were the primary focus on last researches (Pauksztat, 2017; Jepsen, 2015). However, surprisingly little is known about the physical work-demand that seafaring required in term of movements and posture adopted by seafarers while performing work tasks. To identify relevant aspects of seafaring work demands, a new approach is needed comparing the functional capacities of seafarers against the physical demands of the job. The purpose of this research project is to identify physical demands of seafaring work through a new experimental approach, based on video analysis of seafarer performance during work. The expected outcome of this research project are follows.

First, identifies physical job demands of seafaring in terms of number of LIWA; total time of LIWA; number of HIWA; total time of HIWA. These dependent variables will compare between independent variables regarding rank (Deck Officers, Deck Crew, Engine Officers, Engine Crew, Galley Staff), and working experience.

Second, extending research on seafarers' well-being identifying the biomechanical loads of job tasks for the five occupations under observation (Deck Officers, Deck Crew, Engine Officers, Engine Crew, Galley Staff), to assess the potential risk of musculoskeletal injury in these job tasks.

Lastly, data and evidence explored in the research project can provide a valuable starting point for preventive action aim to long-term benefits of seafarer's physical well-being.

# Chapter one: Epidemiological analysis of cardiovascular diseases among seafarers

In this chapter we have analyzed the epidemiology of the most relevant cardiovascular disorders affecting seafarers. This chapter focuses on conducting an epidemiological analysis of CVDs among seafarers. Understanding the prevalence, risk factors, and impact of CVDs within this unique occupational group is essential for improving their health and well-being. Additionally, this analysis contributes to a broader understanding of the global burden of CVDs risk factors. The primary objectives of this chapter are as follows:

1. To provide an overview of the maritime industry and the specific health challenges faced by seafarers.
2. To analyze the prevalence of CVDs among seafarers and the associated risk factors.
3. To discuss the implications of CVDs on seafarer health, safety, and job performance.

## 1.1 A descriptive epidemiological study of cardiovascular diseases among seafarers

### 1.1.1. Introduction

Cardiovascular diseases (CVD) are the term defining several pathologies affecting the cardiovascular system. These include coronary heart disease, cerebrovascular disease, peripheral arterial disease, rheumatic and congenital heart diseases, and venous thromboembolism (World Health Organization, 2016]. CVD is the leading cause of death worldwide, with approximately 17.9 million people dying per year and representing 31% of all global deaths. Of these deaths, about 7.4 million and 6.7 million were due to coronary heart disease and stroke, respectively (World Health Organization, 2017). In 2015, more than 1.6 million seafarers were employed worldwide, of which approximately 775,000 and 875,000 were officers and ratings, respectively (B.I.M.C.O. and I.C.S., 2019). In general, nautical work is broadly grouped by working place on board ships, including deck, engine, and galley (Lefkowitz, 2018), based on the differences between professional duties on board. CVD is the number one cause of death among seafarers, and the mortality rates on board are higher than those observed on shore (Oldenburg, 2019; Alves, 2010; Grappasonni, 2012). Workers at sea have high mortality, injuries, and illnesses, probably consequently that they are working in hazardous environments. Different studies revealed that modifiable lifestyles such as tobacco use, harmful use of alcohol, physical inactivity, and unhealthy diet together with other significant risk factors, including increased arterial pressure, blood glucose levels, elevated blood lipids, overweight, and obesity, are the most critical. The above risk factors are causally linked with CVD, which represent the leading causes of deaths and disability in most countries (Rabani, 2018; Yang, 2012Buring, 1990;). Overweight and obesity represent relevant CVD risk factors for seafarers, and in these workers occur more often than in the general population (Szafran-Dobrowolska, 2019). A study conducted on the board of Italian flagship (2019) reported that more than 40% and 10% of seafarers were overweight and obese, respectively (Nittari, 2019). Another work on Iranian seafarers revealed that overweight increased from 46.7% to 60.9% over the period of 3 years (Baygi, 2017). These results indicate that in seafarers' CVD risk factors become worse compared to ashore workers. Other risk factors like gender, stress, depression and age are causes of CVD, and the reduction of these risk factors decreases the burden of CVD in all age groups (Heart Foundation, 2013). Mental, psychological, and physical stressors represent other factors influenced by work-related issues (Carotenuto, 2012). These include isolation from family, long working hours, lack of shore leave, fatigue, exposure to different unhealthy lifestyles, and others (Allen, 2008; Iversen, 2012; MacLachlan, 2012) and make seafarers at a higher risk of CVD than the general population. Ischemic heart disease (IHD) and stroke are the principal components of the CVD burden globally and contributed to approximately 15.2 million deaths in 2015 (Wang, 2016; Joseph, 2017). This accounts for more than 85% of all deaths due to CVD in the same year (Wang, 2016). IHD and stroke cases increased, from 7.3 to 8.93 million and from 5.29 to 6.17 million deaths, respectively, between 2007 and 2017 (Roth, 2017). The incidence and mortality rate of IHD has decreased in high-income countries in the last 25 years (Moran, 2014). In contrast, the prevalence and mortality rate for this pathology is increased remarkably with age in developing countries and Eastern Europe (Joseph, 2017). This suggests that CVD is reversing in developed countries and needs more attention in developing countries (Roth, 2018). To meet the global health policy goal of reducing CVDs, further analysis of epidemiological data focusing on location, age, and time patterns is important (Roth, 2018). This is because countering risk factors represents a health target in sustainable development goals for CVD reduction (Go, 2014). In addition, the global efforts to reduce the CVD burden should be evidence-based (Roth, 2018) and centered on analyzing the prevalence trends of these disorders. Cardiovascular disease needs attention in commercial maritime operations because a high proportion of CVD death rate was recorded at sea among sailing seafarers (Roberts, 2002; Hansen, 1986; Puttfarken, 1996). Moreover, seafarers are exposed to different work-related stressors and potential complications like the risk of sudden cardiac arrest. In view of this, studies should provide evidence-based information about the CVD burden in the case of seafarers to handle events effectively (Alves, 2010). The present work has evaluated the CVD distribution and differences between the rank and the seafarers' worksite. The analysis was made based on medical assistance data to seafarers provided by Centro Internazionale Radio Medico (International Radio Medical Centre, C.I.R.M.), the Italian Telemedical Maritime Assistance Service (TMAS).

### 1.1.2 Materials and Methods

A descriptive epidemiological study was used to evaluate the distribution and differences in CVD occurrence between occupational groups and seafarers' worksites from 2010 to 2018.

Data were obtained from the C.I.R.M. database. C.I.R.M. is a non-profit institution established in 1935 which provides worldwide telemedical assistance to sailing seafarers (34). The Centre was appointed in 2002 as the Italian TMAS and is the type of organization with the largest experience worldwide in terms of the number of patients assisted on board ships. For the last 84 years (from April 1935 to December 2019), the C.I.R.M. assisted more than 101,600 patients' on-board ships and received 686,163 calls for medical consultations, with an average of 6 calls per patient. Data of C.I.R.M. assistance are available for each year with their gender, age, country, duties, and the diagnosis was encoded by both World Health Organization (WHO) International Classification of Diseases (ICD) 9th and ICD 10th versions. We used for this study data from 2010 to 2018 because, until 2009, data were encoded by ICD 9th version, but we considered 2010 and onwards data in which diagnoses were classified according to the ICD 10th version. In this version, the cardiovascular disease ICD code is from I00–I99. Diseases affecting seafarers were therefore classified into IHD (I20–I25), hypertensive disease (I10–I15), acute rheumatic fever (I00–I02), chronic rheumatic heart disease (I05–I09), pulmonary heart disease, and diseases of pulmonary circulation (I26–I28). Other forms of heart disease (I30–I52), cerebrovascular disease (I60–I69), diseases of arteries, arterioles, and capillaries (I70–I79), diseases of veins, lymphatic vessels, and lymph nodes, not elsewhere classified (I80–I89) and unspecified disorders of the circulatory system (I95–I99) (35) were also considered.

All recorded medical data are stored in the C.I.R.M. database, which is not accessible for externals. Data extraction, compiling, and coding were then performed. The attributes collected from each diagnosis were age, gender, occupational rank, and worksite. Age was calculated by subtracting the seafarer's date of birth from the date of medical advice provision. Seafarers, the date of birth of which was not available, were excluded from this study.

Descriptive analysis of seafarers' demographic variables, including age, gender, rank, and worksite, was done to evaluate the distribution of CVDs. Quantitative attributes like age and sex were encoded and categorized. For example, the age of seafarers was categorized into five groups: less than or equal to 30 years (age group 1), 31–40 years (age group 2), 41–50 years (age group 3), 51–60 years (age group 4) and older than 60 years (age group 5). Occupational rank was stratified by officers (deck and engine officers) and non-officers (deck and engine ratings, and galley), whereas worksites were categorized into three groups, namely deck, engine, and galley. Chi-square or Fisher's exact test was used to analyses distributional differences in rank and worksite groups. Data analysis was made using the IBM SPSS Statistics software version 26.

### 1.1.3. Results

Overall, 1,377 CVD cases were assisted by C.I.R.M. during the 9 years under study. Almost all (98%) seafarers examined with CVD were male, and the average age (± standard deviation) of the patients with CVDs was 48.35 ± 12.71 years. CVD was frequently diagnosed in seafarers aged 51–60 years (31% of all seafarers with CVD). CVD occurred more often in non-officers compared to officers (748 (54.3%) vs. 629 (45.7%)) and was almost 2 and 9 times more frequent in the deck than in the engine and galley workers (Table 1). Cardiovascular disease was the sixth leading cause for accessing the C.I.R.M. Other cases such as gastrointestinal disease and injury/trauma were the first and second most frequent causes of pathologies assisted among seafarers and accounted for 5,372 (16.60%) and 5,330 (16.40%) of all medical events, respectively, during the study period (Fig. 1). The frequencies of different CVD diagnoses are shown in Figure 1. The most frequent CVD were hypertensive diseases (n = 551; 40%) and IHD (n = 530; 38.5%). Among hypertensive diseases, arterial hypertension was the most frequently diagnosed (89% of the total hypertensive diseases), whereas other types of hypertensive diseases such as hypertensive heart disease, renal diseases, and secondary hypertension accounted for 11% of the total hypertensive diseases. IHD included unspecified angina pectoris (376 cases), acute myocardial infarction (132 cases), and other forms of angina pectoris (22 cases).

| Variable | Number of cases (n = 1,377) | Frequency (%) |
|---|---|---|
| **Age group** | | |
| ≤ 30 | 133 | 9.7 |
| 31–40 | 231 | 16.8 |
| 41–50 | 385 | 28 |
| 51–60 | 429 | 31 |
| > 60 | 199 | 14.5 |
| Mean (SD) | 48.35 ± 12.71 | |
| **Gender** | | |
| Male | 1,345 | 98 |
| Female | 32 | 2 |
| **Rank** | | |
| Officer | 629 | 45.7 |
| Non-officer | 748 | 54.3 |
| **Worksite** | | |
| Deck | 807 | 59 |
| Engine | 479 | 35 |
| Galley | 91 | 6 |

SD — standard deviation

*Table 1. Demographic characteristics of seafarers with cardiovascular disease from 2010 to 2018*

The other heart disease forms were the third most often diagnosed CVD, accounting for approximately 7% (95) of pathologies of this group. A common diagnosis of other forms of heart disease included cardiac arrest (62 cases), paroxysmal tachycardia (26 cases), and other cardiac arrhythmias (7 cases). Cerebrovascular diseases were also diagnosed in 59 seafarers and accounted for over 4% of total CVD. The most often cerebrovascular diagnosis included stroke, which is responsible for 80% of total cerebrovascular cases. Cerebral infarction accounted for the remaining 20% of cerebrovascular diseases Diseases of veins and lymphatic vessels were responsible for nearly 4% (50) of medical advice requests received. 91% of these pathologies included phlebitis and thrombophlebitis. The remaining 9% consisted of portal vein thrombosis and varicose veins of other sites.

The average age of officers and non-officers with CVD was 48.21 ± 13.08 years and 48.47 ± 12.44 years, respectively. CVD was frequently diagnosed in officers aged 41 to 50 years and in non-officers aged 51 and 60 years during the study period (Fig. 3). Officers were frequently diagnosed with hypertensive Officers were frequently diagnosed with hypertensives (46%), whereas non-officers were often diagnosed with IHDs (41%). The observed frequencies and percentages of each type of CVD diagnosis by seafarer rank are summarised in Table 2. The distribution of CVD diagnosis between officers and non-officers was significantly different (x2 (5) = 17.308, p = 0.004) (Table 2).

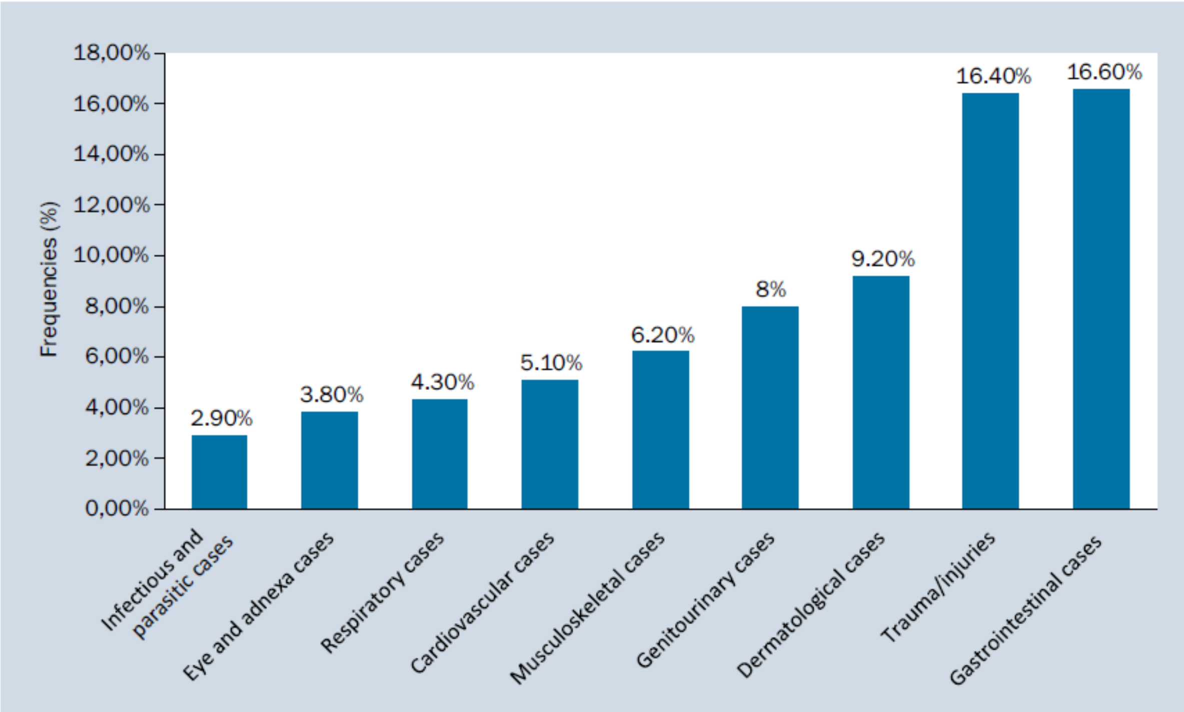


*Figure 1. Frequencies (%) of pathologies assisted by Centro Internazionale Radio Medico (International Radio Medical Centre, C.I.R.M.) from 2010 to 2018*

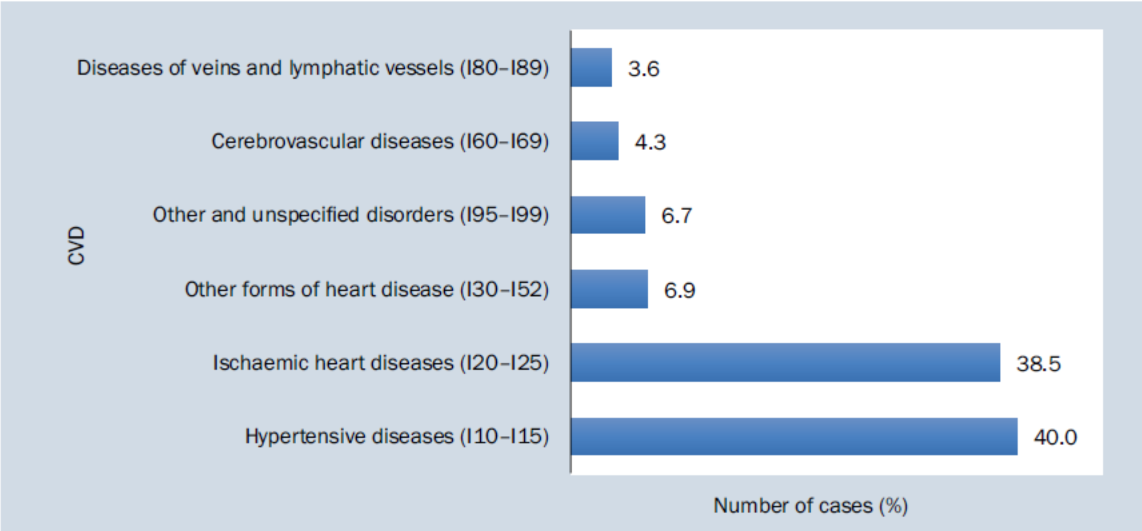


*Figure 2. Frequencies (%) of cardiovascular diseases (CVD) diagnosis according to World Health Organization (WHO) International Classification of Diseases (ICD) 10th category from 2010 to 2018 (n = 1,377)*

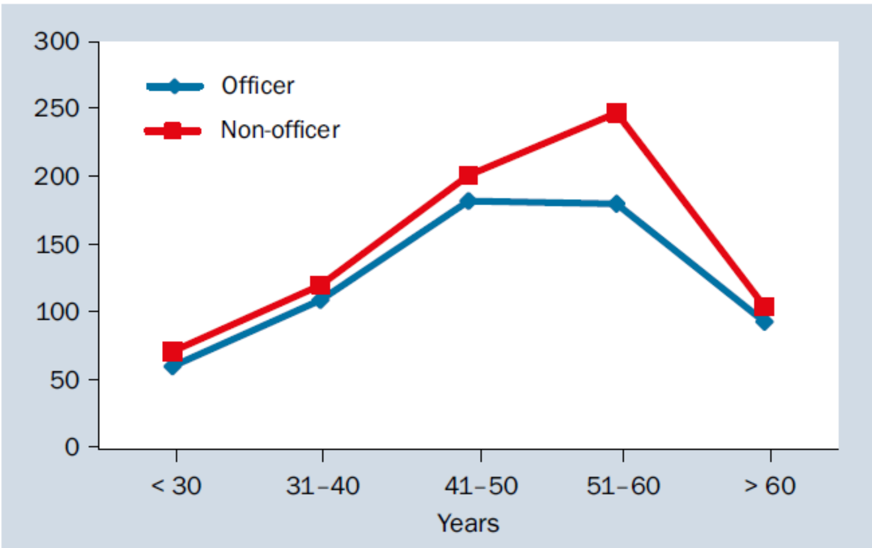


*Figure 3. Distribution of cardiovascular diseases by age group between officers and non-officers with cardiovascular cases from 2010 to 2018*

We found that deck workers were often diagnosed with IHD (41.9%), while engine room workers (43.8%) and galley (46.2%) were frequently diagnosed with hypertensive diseases There was no difference in distribution of CVD diagnosis between worksite groups (x2 (10) = 12.863, p = 0.231) (Table 3).

| Types of cardiovascular diseases | Rank | | P-value |
|---|---|---|---|
| | Officer | Non-officer | |
| Total | 629 (100) | 748 (100) | 0.004 |
| Hypertensive diseases (I10–I15) | 288 (46%) | 263 (35%) | |
| Ischaemic heart diseases (I20–I25) | 220 (35%) | 310 (41%) | |
| Other forms of heart disease (I30–I52) | 39 (6%) | 56 (7%) | |
| Cerebrovascular diseases (I60–I69) | 21 (3%) | 38 (5%) | |
| Diseases of veins and lymphatic vessels (I80–I89) | 23 (4%) | 27 (4%) | |
| Other and unspecified disorders (I95–I99) | 38 (6%) | 54 (7%) | |

*Table 2. Distribution of cardiovascular diseases by seafarer rank from 2010 to 2018 (n = 1,377)*

| Types of cardiovascular diseases | Worksites | | | P-value |
|---|---|---|---|---|
| | Deck | Engine | Galley | |
| Total | 807 (100%) | 479 (100%) | 91 (100%) | 0.231 |
| Hypertensive diseases (I10–I15) | 299 (37%) | 210 (43.8%) | 42 (46.2%) | |
| Ischaemic Heart diseases (I20–I25) | 338 (41.9%) | 162 (33.8%) | 30 (32.9%) | |
| Other forms of heart disease (I30–I52) | 54 (6.7%) | 35 (7.3%) | 6 (6.6%) | |
| Cerebrovascular diseases (I60–I69) | 36 (4.5%) | 20 (4.2%) | 3 (3.3%) | |
| Diseases of veins and lymphatic vessels (I80–I89) | 32 (3.9%) | 15 (3.2%) | 3 (3.3%) | |
| Other and unspecified disorders (I95–I99) | 48 (5.9%) | 37 (7.7%) | 7 (7.7%) | |

*Table 3. Distribution of cardiovascular diseases by seafarer worksites from 2010 to 2018 (n = 1,377)*

### 1.1.4. Discussion

Over 9 years (from 2010 to 2018), there were 1,377 contacts to C.I.R.M due to CVD. Among the medical advice requests, 40% and 38.5% were respectively for hypertensive and IHD. The remaining 21.5% were for other heart disease forms, cerebrovascular diseases, diseases of veins and lymphatic vessels, and unspecified disorders of the circulatory system. In this study, we focused on the distribution and differences of CVD between the rank and the seafarers' worksite groups based on the assistance data of C.I.R.M. This type of analysis was chosen for practical reasons because it is difficult to estimate the incidence of CVD among seafarers without information on the total at-risk seafarer population on board ships. In this study, we found that CVD was the sixth leading cause of accessing C.I.R.M. medical services. These results are not consistent with a German study (Oldenburg, 2014) but in line with research conducted in the United States merchant vessels (Alves, 2010). Nevertheless, these diseases are critical and one of the main health problems for seafarers. This is because factors such as exposure to the noise, job strain, and fatigue could increase CVD risk among seafarers. On the other hand, seafarers stay for long times away from their families, and they are experiencing many work-related issues such as physical, mental, and psychological stressors that can exacerbate the risk of developing CVD. Another study conducted on seafarers reported that vessel-specific stress, unhealthy diet, and lack of exercise were the major risk factor for CVD on board. This could be the reason for the not negligible occurrence of CVD among seafarers (Tu, 2016) in spite of the rather frequent cardiovascular pre-employment tests that people working at sea should make every 2 years. A study conducted in the modern maritime industry reported several work-related cardiac risk factors such as time pressure, long working hours, and high-stress factors are present on board (Oldenburg, 2010). The present study has shown that CVD distribution between officers and non-officers was significantly different ($x2$ (5) = 17.308, $p = 0.004$), with non-officers having more CVD diagnoses than officers. This may be due to differences in stress management, lifestyle risk factors, and high work-related stressors. In addition, a recently conducted study among seafarers revealed that non-officers required a high level of physical effort to carry out their duties, and they had a higher risk of psychological stress than officers because of work-related risk factors (Tu, 2016). This may explain our findings of different frequencies of CVD diagnoses between officers and non-officers. In contrast, no significant differences in CVD diagnosis by seafarer's worksite were noticeable.

In this study, hypertensive disease was the most common CVD, accounting for 40% of all cardiovascular cases. Arterial hypertension with 89% of diagnoses was the main CVD affecting seafarers. A Danish study revealed that arterial hypertension was the main health concern of seafarers. The same study reported 44.7% and 41.8% of the prevalence of hypertension and pre-hypertension, respectively, among Danish seafarers (Tu, 2016). According to different studies, the prevalence of CVD was increased among seafarers because of unhealthy lifestyles such as smoking, a high-fat diet, and inadequate physical activity (Oldenburg, 2014). This may explain our findings of the elevated frequency of hypertensive disease diagnoses. Ischemic heart disease was the second most frequent disorder in the present work, accounting for 39% of all cardiovascular diseases. The basic medical assistance level that can be offered to on board ships without doctors or adequately trained paramedics, complicated by the relevant limitations in terms of availability of diagnostic devices on board, makes our analysis rather generic. For instance, situations like unspecified angina pectoris would need additional tests to confirm the condition, but unfortunately, this is not possible in the large majority of merchant ships (6, 40). Moreover, devices for precise CVD diagnoses such as electrocardiogram, echocardiogram, coronary angiogram, and myocardial imaging to minimize misdiagnosis and prevent treatment delay remain today a dream far becoming a reality. Despite the above limitations, our analysis, based on requests coming from the ship side at the time of occurrence of symptoms requiring medical care, represents a real-life survey of what happens in an isolated environment like a ship in the middle of the sea.

The present study showed that CVD frequently occurred in older seafarers on board, with 31% (429) of all CVD cases affecting people aged between 51 to 60 years. In other words, the distribution of CVD among older seafarers is threefold higher than in younger seafarers (less than or equal to 30 years). Our results are in line with those of a German study reporting that CVD distribution significantly varied between age groups among seafarers (Oldenburg, 2010). In other words, as expected, increasing age is associated with a higher likelihood of CVD. This observation should consider more deep fitting tests in older seafarers and an effective preventative measure targeting older age seafarers on board.

This study has some limitations and strengths. It was a retrospective descriptive study, and in nature, it has its constraints, including variable incomplete. Other limitations are gender disproportion and not considering the nationality variable because these attributes for some seafarers were incomplete in the database. We have also not assessed the incidence rate or cumulative incidence because of the lack of control group data. However, this study has some strengths. This work has shown the case frequency and differences between occupational groups. This can give insights into cardiovascular problems' real occurrence and stimulate future incidence of CVD studies in merchant seafarers.

### 1.1.5 Conclusions

Non-officers had a higher frequency of CVD diagnosis compared to officers during the study period. Officers were frequently diagnosed with hypertensive CVDs, whereas non-officers often diagnosed with IHDs. Older seafarers aged 51 to 60 were the age group with a higher frequency of CVD. To prevent CVD distribution and reduce their burden on merchant seafarers, effective prevention measures such as early diagnosis, regular follow-up, a training crewmembers on basic life support and using automatic external defibrillators should be considered. In addition, telemonitoring equipment for cardiovascular diagnosis via telemedicine should be introduced on a large scale on board to guarantee higher quality medical assistance to sailing seafarers. Special attention should also be given to seafarers older than 50 years. Primary prevention focused on increased awareness of CVD risk factors, intensive health education campaigns, and regular medical check-ups on board should be considered with full attention.

## 1.2 Risk prediction model of self-reported hypertension for telemedicine based on the sociodemographic, occupational and health-related characteristics of seafarers: a cross-sectional epidemiological study

This study was conducted among seafarers aboard ships. Data on sociodemographic, occupational and health-related characteristics were collected using anonymous, standardized questionnaires. This study involved 8125 seafarers aged 18–70 aboard 400 vessels between November 2020 and December 2020. 4318 study subjects were included in the analysis. Seafarers over 18 years of age, active (on duty) during the study and willing to give informed consent were the inclusion criteria. risk prediction model developed in the present study is accurate in predicting self-reported hypertension in seafarers' onboard ships.

### 1.2.1 Introduction

Arterial hypertension is well known as one of the most common risk factors for cardiovascular disease (CVD). According to the WHO, approximately 1.28 billion adults in the world (aged 30–70) suffer from hypertension, of which 46% were unaware that they had high blood pressure (Roberts, 2010). CVDs are one of the leading causes of work-related mortality from disease in the maritime industry (Grappasonni, 2012; Sagaro, 2021) and their burden is attributable to mainly modifiable risk factors (Sagaro, 2021). Due to work-related stressors, modifiable CVD risk factors, such as high body mass index (BMI) and cigarette smoking, were more prevalent in seafarers as compared with ashore workers (Mingshan, 2020) As for medical care at sea, the captain or captain's delegated deck officer oversees medical assistance to seafarers in the event of an emergency on board.9 This is because cargo ships do not carry doctors or other adequately trained health professionals.10 As a result, ship officers with medical duties on board consult doctors at the Telemedical Maritime Assistance Service (TMAS) Center for diagnosis and emergency treatment (Sagaro, 2020; Mahdi, 2016). In view of this, until the crew arrives in port or healthcare professionals are available, it may be necessary for the crew to provide first aid at sea for several days. On board, therefore, identifying and treating crew members with CVD risk factors are more challenging than on land.

In the present context, a risk prediction model can be defined as a logistic regression equation that offers a method for estimating the likelihood of having a health outcome based on patient characteristics or risk factors (Pavlou, 2015). This method can be used to determine an individual's risk of modifiable CVD risk factors through assessing their characteristics. A risk model can also help healthcare professionals in decision-making. In the general population, a risk model in the context of CVD risk factors (hypertension, diabetes and other modifiable risk factors) is well documented as a means of assessing individual risk based on different variables (Liu, 2019; Zhao, 2017; Ahmad, 2014). So far, no studies on a risk prediction model have been conducted in seafarers in order to assess their individual risk for self-reported hypertension (HTN). It is possible that a risk model will have a positive effect on mitigating risk factors and reducing the burden of CVD among seafarers, who reside hundreds of kilometers from healthcare facilities.

A variety of factors influence the health and living conditions of seafarers in their working environment. Furthermore, many international seafarers undertake long-term voyages (tours) at sea for periods of at least 4 to 6 months at a time (Mahdi, 2016). The reality is that seafarers work offshore and travel frequently, so they are not able to regularly monitor their blood pressure like workers ashore. Therefore, these individuals will have less possibility of knowing that their blood pressure may rise, since the majority of individuals with high blood pressure do not exhibit symptoms (World health organization, 2021). As far as healthcare is concerned, prompt attention in case of a medical emergency can be a matter of life and death on board a vessel. Thus, by developing a risk prediction model for HTN, early detection will be possible, the crew at risk will be identified, and motivation for therapy adherence and lifestyle changes will be enhanced. The model can predict the probability of HTN using seafarer's characteristic data that is collected via telemedicine. Moreover, the model can be used to calculate the risk score of HTN, and the risk can be presented using a logistic model, which can be useful in the communication of risk.

The present study was aimed to develop a risk prediction model of HTN for telemedicine based on the sociodemographic, occupation and health-related characteristics of seafarers. This to assist in alerting crew members who have not reported hypertension or seafarers who do not get blood pressure measurements regularly. In this way, the risk model would allow TMAS doctors or other healthcare professionals to predict the likelihood of HTN in seafarers based on their sociodemographic and occupational characteristics. Using this method, TMAS physicians can predict whether the crew is at risk of HTN during a telemedicine consultation and recommend appropriate actions accordingly.

### 1.2.2 Materials and Methods

Cross-sectional epidemiological study was conducted on board ships to determine the prevalence of self- reported hypertension and develop a risk prediction model to assist in early identification of high-risk groups and allow preventative measures to be taken. Data were collected between 1 November 2020 and 31 December 2020.

The study subjects were recruited through International Radio Medical Center (Centro Internazionale Radio Medico, C.I.R.M.), the Italian TMAS Center. It is one of the oldest and most well-known TMAS centres in the world regarding the number of patients assisted at sea. A simple random sampling method was used in order to select 400 ships from 5000 ship contact lists. A second step in the research process was to present the goal and protocol of the study to all captains of enrolled vessels to request their permission to submit a self-reported anonymous questionnaire and request a list of seafarers per ship. If the captains agreed to participate in the study, they were asked to provide a list of the active seafarers onboard each ship during the period of study. We obtained the names, ages and ranks of 8125 seafarers from a sample of 400 ships. Seafarers over the age of 18, active (on duty) during the period of the study, and willing to give informed consent were the inclusion criteria. Maritime recruitment policies, according to the International Labor Organization, restrict the age of seafarers (ILO Labour Convention, 2006). Due to this, the crew members included on the list were eligible for this study because they were all over the age of 18. By collaborating with the C.I.R.M. physicians, we offered a 1-day videoconference training to the ship officers with medical duties on board on survey administration as well as how to obtain bodyweight and height measurements of the subjects. Thereafter, the C.I.R.M. sent the data collection tool to telemedicine case managers via email, accompanied by an invitation letter and consent forms. A trained case manager was then assigned per vessel to administer the survey. In the invitation letter, an introduction to the purpose of the study, the procedures, the declarations of anonymity of the participants and statements regarding their voluntary participation are explained. The participants were assured of the confidentiality and privacy of their responses. Candidates who were interested in participating in the study provided their signed informed consent before participating.

| Variables | Description |
| --- | --- |
| Socio-demographic | |
| Age | Continuous: age of study participants |
| Marital status | Dummy: single=0; married=1 |
| Educational levels | Dummy: Junior school and below=1; high and technical school=2; college and above=3, |
| Nationality | Dummy: non-EU countries=0; EU-countries=1 |
| Occupation-related | |
| Working hours per week | Continuous: Working hours per week of participants |
| Work experiences at sea | Dummy: less 10 years=0; 10+years = 1 |
| Rank | Dummy: officers (captain, deck officers and engine officers) = 0; non-officers (deck crew, engine crew and galley) = 1 |
| Worksites | Dummy: deck=1; engine=2; galley=3 |
| Health-related | |
| Smoking status | Dummy: no=0; yes=1 |
| Alcohol consumption | Dummy: no=0; yes=1 |
| Snoring | Dummy: no=0; yes=1 |
| BMI | Continuous: BMI of study participants |

BMI, body mass index.

Table 4 Independent variables and their descriptions

This study used an anonymous, standardised questionnaire. This survey was designed to ask a series of questions that included sociodemographic characteristics (age, marital status, educational levels and nationality), occupation-related characteristics (working hours per week, work experiences at sea, rank, work location) and health-related characteristics (snoring, smoking status, alcohol consumption, BMI and HTN). The majority of data, except for weight and height, were collected through self-reporting. The questions below were used to ascertain the presence of high blood pressure as well as its measurement. Have you ever been told by a doctor or other healthcare worker that you have hypertension? In the above question, there are two choices: ‘yes’ and ‘no’. Study subjects who answered ‘yes’ to the above question, were then asked: 'Are you currently taking any medication for high blood pressure?' This question has two options as well, 'yes' and 'no.' Study subjects who answered 'yes' to the medication question above were also asked to indicate the name and dose of the antihypertensive medication they were currently taking. In this study, high blood pressure (hypertension) was defined as having previously been diagnosed with hypertension and currently taking medication for hypertension. The consumption of alcohol was assessed by asking the question, 'Have you consumed alcoholic beverages within the last 12 months, including today?'. Those subjects who answered 'yes' to the above question were also asked about their frequency of alcohol consumption and the number of standard drinks they consumed per day to determine the amount of alcohol consumed. Subjects who answered 'no' were considered non-drinkers.

To assess self-reported smoking habits, we asked participants, 'Do you currently smoke tobacco products?' There are two options for the question, 'yes' and 'no'. Participants who answered 'yes' to the above question were also asked: 'Do you currently smoke tobacco products every day?' Again, those participants who answered 'yes' to the previous question also rated how many years they had smoked cigarettes non-stop. In the present study, current smoking was defined as participants who smoked cigarettes regularly for 1 year and did not quit smoking tobacco products for at least 6 months. As per the WHO guideline, (World Health Organization, 2000) the body weight and height of the participants were measured. The BMI was computed as follows: weight in kilograms (kg) divided by height in meters (m) squared (weight (kg)/height (m)2). Regarding snoring, self-reported snoring was assessed by the question 'Do you snore when you sleep?' Those who responded 'yes' were further questioned about the frequency of snoring per week.

We conducted an analysis of descriptive statistics to compare participants with and without HTN based on their characteristics. HTN was considered a dependent variable in this study and was coded 0 for no HTN and 1 for HTN. Continuous characteristics (age, working hours per week and BMI) were reported as the mean and SD and were compared using a t-test, while categorical characteristics (marital status, educational level, nationality, work experience, rank, worksite, current smoking status, snoring and alcohol consumption) were reported as frequencies and percentages and compared using a $\chi 2$ test. We conducted univariable and multivariable logistic regression analyses to identify risk factors associated with HTN. Before conducting the analysis, we assigned codes for independent variables that were categorical. Table 4 shows a description of the independent variables.

To determine which risk factors should be included in the univariable analysis and the multivariable logistic regression model, then to include in the final risk prediction model, a comprehensive review of previously published studies and consultation with TMAS healthcare providers were conducted. The variables identified in the data set as relevant to clinical practice via telemedicine were considered in the analysis. This approach could help to identify potential risk factors for HTN. An independent variable with a p value less than 0.25 in the univariable analysis was considered a candidate for multivariable analysis. Accordingly, variables such as age, working hours per week, work experience at sea, BMI, rank, nationality, worksites, current smoking, snoring status, alcohol consumption, marital status and educational levels were selected and included in multiple logistic regression model for the construction of the risk prediction model. Then we conducted multivariable analysis using the backward variable selection method using a significance level of p value less than 0.05, and the variables which were not significantly associated with HTN in the multivariable logistic regression model were systematically dropped. The explanatory variables with p values less than 0.05 in the multivariable logistic regression model were considered independent predictors of HTN and included in a risk prediction model. Furthermore, for each independent variable included in both univariable and multivariable logistic regression models, unadjusted ORs, adjusted ORs (AORs), 95% CIs and p values were reported.

As part of the model checking, we examined the interaction between risk factors. BMI and snoring were the only interaction terms statistically significant ($p<0.001$) in the model with the interaction terms. Nevertheless, we conducted several statistical analyses to compare the model's fit with and without interaction terms. For example, we performed the analysis of the deviance table, confusion matrix, Akaike information criteria (AIC), Bayesian information criteria (BIC) and area under the receiver operating characteristic (ROC) curve. Accordingly, the model's overall accuracy, AUC, BIC and AIC value with interaction terms were, respectively, 85.3% (95% CI 84.3% to 86.4%), 86.5%, 3024.32% and 2954.25%. By contrast, the BIC and AIC values of a model without interaction terms were 2994.35 and 2905.16. Due to its greater predictive power to estimate HTN, the model without interaction terms was selected as the final risk prediction model. and AIC value with interaction terms were, respectively, 85.3% (95% CI 84.3% to 86.4%), 86.5%, 3024.32% and 2954.25%. By contrast, the BIC and AIC values of a model without interaction terms were 2994.35 and 2905.16. Due to its greater predictive power to estimate HTN, the model without interaction terms was selected as the final risk prediction model.

A logistic regression equation was used to calculate the HTN risk for each seafarer based on the regression coefficients from the multiple logistic regression model for each predictor that was statistically significant in its association with HTN. Therefore, the logistic regression model predicts the logit of HTN based on independent predictors:

$$\text{Logit (HTN)} = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots \beta_i X_i \qquad (1)$$

Therefore, the probability of predicted (pp) HTN was determined as follows:

$$\text{pp (HTN} \mid \text{X1, X2, X3, ...Xi)} = \frac{\exp\left(\alpha + \beta 1X1 + \beta 2X2 + \beta 3X3 + \ldots \beta iXi\right)}{1 + \exp\left(\alpha + \beta 1X1 + \beta 2X2 + \beta 3X3 + \ldots \beta iXi\right)} \qquad (2)$$

Where α is the value of intercept, βi are regression coefficients, $X_i$ are the sets of predictors.

An ROC was used to assess the final model's discriminative ability. The area under the ROC curve is a plot of sensitivity, which is true positive rates versus false-positive rates (1-specificity) for consecutive cut-off values for the predicted risk. In particular, we computed the specificity and sensitivity of the resulting multiple logistic regression model by constructing ROC curves and determined the area under the curve (AUC). The area under the ROC curve describes the predictive power of the final model that is, how well it distinguishes between seafarers with and without outcomes. The AUC, which ranged from 0 to 1, provides a measure of the ability of the final model to discriminate. Accordingly, AUC of 0.5 indicates that the model has no discrimination (the predicted probabilities are purely random); if AUC values from >0.5 to <0.7, the model has poor discrimination, if AUC values >0.7 to <0.8, the model is generally considered to have good or acceptable discrimination, if AUC values >0.8, the model is considered to have excellent discrimination.

The Hosmer-Lemeshow goodness-of- fit statistic was used to measure calibration. The Hosmer-Lemshow test is commonly used to evaluate a model's overall goodness of fit. The test is based on χ2 with Q-2 df, where Q is the group interval within the dataset. A non-significant p value (p>0.05) indicates that a risk prediction model performs well and can be used for predictive purposes. To ensure that a risk prediction model can accurately predict the outcome of interest, it is imperative to perform this test.

We employed Pseudo-R2 statistics to assess the predictive strength of the model by comparing a model without any predictor (null model) to a model including all predictors (full model). (Cox, 1989; Hu, 2006) Pseudo-R2 statistics, such as Cox and Snell, Nagelkerke and McFadden provide a measure of the predictive strength of a logistic regression model. These statistics compare a model with all predictors to a model without any predictors, allowing us to assess the improvement in predictive power. For instance, the McFadden pseudo-R2 statistic is used to measure predictive strength in logistic regression. McFadden's pseudo R2 is defined as one minus the ratio of the log-likelihood with a null model to the log-likelihood with a full model. The resulting value ranges from 0 to 1, with a higher value indicating a stronger predictive power of the model. Another way to assess the fit of the model is to classify the cases. The classification table can be used to evaluate how well the model fits the data, which gives a measure of the model's predictive capacity (Stevens, 1992). This model is used to classify each record using calculated probabilities between 0 and 1, with a cut-off value of 0.50. Consequently, the data records are assigned the value of 1 if the predicted probability is greater than 0.5 and 0 if the predicted probability is less than 0.5. We then used a classification table to calculate accuracy, sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) to assess the model's predictability and correct classification. All statistical analyses were performed using R-software, 24 V.4.0.2 (The R Foundation for Statistical Computing, Vienna, Austria). R-package 'dplyr' was used for data manipulation, (Wickman, 2021) and R-package 'summarytools' was used for frequencies tables, cross-tabulation and other descriptive statistics. (Comtois, 2020) R-package 'glm2' was used for running the univariable and multivariable analysis. (Marschner, 2011) Its function 'glm' was used to fit the described model for different tested sets of independent variables and categorizations of those variables. In this study, statistical significance was determined by a p value of less than 0.05.

This study was developed in collaboration with an Italian TMAS physicians. The study participants were not directly involved in the design, recruitment of participants, conduct, reporting or dissemination plans of this study. We intend to disseminate the findings to the collaborating TMAS, which provides health services for seafarers on board ships, as well as to shipping companies, the Inter- national Maritime Organization and other stakeholders.

### 1.2.3 Results

A total of 8125 subjects aged 18 and over were enrolled in this study. In total, 4648 seafarers volunteered to take part in the survey, with a response rate of 57.2%. Of these 4648 participants, 330 were excluded from analysis due to missing data. Finally, 4318 participants were included in the analysis, and the sociodemographic and occupational characteristics of the study participants are presented in table 4. The average age of the participants was 37.95 years (SD: 10.32 years, range: 19–70 years). The mean age of study participants with hypertension was 45.23±9.00. Of 55.3% and 55.5% of the study subjects, respectively, were non-officers and deck workers. Of the 4318 study participants, 20.8% (900) had HTN. The majority (99.4% (4290)) of study participants were men. The average working hours per week of study participants who reported having hypertension were 68.65±11.18. In this study, individuals who reported having hypertension were more likely to work longer hours per week, be elderly, have a higher BMI, be married, hold non-officer positions, work as deck workers, smoke, snore and consume alcohol when compared with those who did not report having hypertension. We found significant differences between those with and without HTN in terms of their sociodemographic (except nationality), occupational and health-related characteristics (table 5).

In the univariable analysis, we found age, BMI, working hours per week, job duration (work experiences) at sea, marital status, educational level, nationality, rank, worksites, smoking status, alcohol consumption and snoring were significant risk factors of HTN ($p<0.25$) (table 6). These variables were also included in the multi- variable logistic regression model. Our multivariable analysis revealed that age (AOR: 1.08, 95% CI 1.07 to 1.10), BMI (AOR: 1.12, 95% CI 1.08 to 1.15), working hours per week (AOR: 1.02, 95% CI 1.01 to 1.03), being non-officers (AOR: 1.75, 95% CI 1.44 to 2.13), work experience (10+ years) (AOR: 1.79, 95% CI 1.33 to 2.42), smoking status (yes) (OR: 5.43, 95% CI 4.49 to 6.59), snoring status (yes) (AOR: 3.58, 95% CI 2.96 to 4.34) and alcohol consumption status (yes) (AOR: 2.19, 95% CI 1.82 to 2.64) were independent predictors of HTN (table 6).

Based on the multivariable analysis, the independent predictors presented in Figure 4 were considered in the final risk prediction model for HTN. We derived the following logistic regression equation for risk prediction model of HTN: Logit (probability of seafarers with HTN): −11.34+0.08 × Age (A)+0.56 × Non-officer (N)–0.20 x Engine (E)–0.66 x Galley (G)+0.58 × Work experiences

(W)+0.02 × Working hours per week (Wr)+1.69 × Smoking (S)+0.78 × Alcohol consumption (Al)+1.28 × Snoring (Sn)+0.11 × BMI

$$PP = \frac{\exp\left(-11.34 + 0.08 \times A + 0.56 \times N - 0.20 \times E - 0.66 \times G + 0.58 \times W + 0.02 \times Wr + 1.69 \times S + 0.78 \times Al + 1.28 \times Sn + 0.11 \times BMI\right)}{1 + \exp\left(-11.34 + 0.08 \times A + 0.56 \times N - 0.20 \times E - 0.66xG + 0.58 \times W + 0.02 \times Wr + 1.69 \times S + 0.78 \times Al + 1.28 \times Sn + 0.11 \times BMI\right)}$$

The overall accuracy (the proportion of true positive and true negative cases) of the present model was 86.5% (95% CI 85.7% to 87.8%). In other words, 86.5% of the subjects are correctly classified by the model. Incorrect cells are referred as false negatives (observed=no, predicted=yes) and false positive (observed=yes, predicted=no). The predictive model's sensitivity, specificity, PPV and NPV were 56.4% (508/ (508+392)), 94.4% (3228/ (3228+190)), 72.8% (508/ (508+190)) and 89.2% (3228/ (3228+392)), respectively. Hence, having a new subject for teleconsultation, we can use this model to predict his/her probability of having HTN.

Based on our analysis, the Hosmer-Lemeshow's good- ness of fit statistics for the multivariable model is appropriate (X2=10.595, p=0.226), indicating that the model fits the data well and can be relied on to make accurate predictions. In terms of a model's predictive strength, the pseudo-R2 estimates (the Cox and Snell pseudo-R2=0.304, Nagelkerke pseudo-R2=0.473 and McFadden pseu- do-R2=0.379) indicate that the predictors contribute substantially to the model's predictive power. The present predictive mode suggested a higher predictive power for evaluating HTN, the ROC curves of the AUC was 0.87 (95% CI 0.86 to 0.88), implying a good ability to discriminate (figure 5).

| Variable | Overall (n=4318 (100%))* | Self-reported hypertension<br>No (n=3418 (79.2%))* | Yes (n=900 (20.8%))* | P value† |
|---|---|---|---|---|
| Age (years) (mean (SD)) | 37.95 (10.32) | 36.03 (9.78) | 45.23 (9.00) | <0.001 |
| Marital status | | | | <0.001 |
| Married | 3015 (69.8%) | 2242 (65.6%) | 773 (85.9%) | |
| Single | 1303 (30.2%) | 1176 (34.4%) | 127 (14.1%) | |
| Educational level | | | | <0.001 |
| College and above | 1741 (40.3%) | 1479 (43.3%) | 262 (29.1%) | |
| Junior school and below | 774 (17.9%) | 564 (16.5%) | 210 (23.3%) | |
| High and technical school | 1803 (41.8%) | 1375 (40.2%) | 428 (47.6%) | |
| Nationality | | | | 0.084 |
| EU countries | 1222 (28.3%) | 946 (27.7%) | 276 (30.7%) | |
| Non-EU countries | 3096 (71.7%) | 2472 (72.3%) | 624 (69.3%) | |
| Rank group | | | | <0.001 |
| Non-officer | 2389 (55.3%) | 1846 (54.0%) | 543 (60.3%) | |
| Officer | 1929 (44.7%) | 1572 (46.0%) | 357 (39.7%) | |
| Work site | | | | <0.001 |
| Deck | 2396 (55.5%) | 1834 (53.7%) | 562 (62.4%) | |
| Engine | 1468 (34.0%) | 1196 (35.0%) | 272 (30.2%) | |
| Galley | 454 (10.5%) | 388 (11.4%) | 66 (7.3%) | |
| Work experience | | | | <0.001 |
| <10 years | 1551 (35.9%) | 1448 (42.4%) | 103 (11.4%) | |
| 10+years | 2767 (64.1%) | 1970 (57.6%) | 797 (88.6%) | |
| Working hours per week (mean (SD)) | 65.96 (10.98) | 65.25 (10.82) | 68.65 (11.18) | <0.001 |
| Smoking status | | | | <0.001 |
| No | 2913 (67.5%) | 2548 (74.5%) | 365 (40.6%) | |
| Yes | 1405 (32.5%) | 870 (25.5%) | 535 (59.4%) | |
| Alcohol consumption | | | | <0.001 |
| No | 2635 (61.0%) | 2273 (66.5%) | 362 (40.2%) | |
| Yes | 1683 (39.0%) | 1145 (33.5%) | 538 (59.8%) | |
| Snoring status | | | | <0.001 |
| No | 3063 (70.9%) | 2678 (78.3%) | 385 (42.8%) | |
| Yes | 1255 (29.1%) | 740 (21.7%) | 515 (57.2%) | |
| Body mass index (mean (SD)) | 25.88 (3.30) | 25.44 (3.14) | 27.56 (3.33) | <0.001 |

*Mean (SD); n (%).
†Welch Two Sample t-test; Pearson's Chi-squared test.

Table 5 Sociodemographic, occupational and health-related characteristics among seafarers with and without self-reported hypertension

### 1.2.3 Discussion

The present study developed a risk prediction model to predict the risk of HTN for telemedicine intervention based on the results of a large cross-sectional epidemiological study and considering the socio demographic, occupational, and health-related characteristics of seafarers. Our study is the first to develop a model that can be used to predict the risk of HTN through tele- medicine. In addition, this study identified predictors associated with HTN. As a result, being a non-officer, age, cigarette smoking, snoring, alcohol consumption, working hours per week, work experience at sea and BMI were independent predictors for HTN. In this study, a risk prediction model demonstrated good predictive accuracy of HTN (86.5% (95% CI 85.7% to 87.8%)). This model could be used as part of a telemedicine intervention at sea as a means of identifying individuals at high risk and assisting with the decision-making process among TMAS healthcare professionals. We found that the area under the ROC curve of a risk prediction model was 0.87, indicating good discriminative ability. The higher the area under the ROC curve, the better the model's ability to separate positive and negative cases. Therefore, a value of 0.87 suggests that the model is reliable in distinguishing between the two classes. The pseudo-$R^2$ statistics, namely, Cox and Snell pseudo-$R^2$=0.304, Nagelkerke pseudo-$R^2$=0.473 and McFadden pseu-do-$R^2$=0.379 reveal that predictors significantly influencea model's predictive power. These values indicate that the chosen predictors contribute significantly to the accuracy and effectiveness of the model in making predictions. The higher the pseudo-R2 value, the stronger the predictive power of the model. In this case, the Nagelkerke R2 value of 0.473 stands out as the highest, suggesting that the predictors considered in the model have a considerable influence on its ability to predict outcomes accurately. This information underscores the importance of the selected predictors in achieving a reliable and robust predictive model. When interpreting these pseudo-R2 statistics, it is important to note that they do not have the same interpretation as R2 in linear regression. Pseudo-R2 statistics in logistic regression measure the proportion of variation explained by the model relative to the null model, rather than the proportion of total variation explained. Our study found that age was a significant risk factor for HTN in seafarers. For every additional year of age, the odds of developing HTN increase by 8.0% (95% CI 1.07 to 1.10). This means that older seafarers are more likely to develop hypertension. With every unit increase in BMI, the odds of developing HTN increase by 12.0% (95% CI 1.08 to 1.15).

| Variable | Unadjusted OR (95% CI) | P-value | Adjusted OR (95% CI)* | P value |
|---|---|---|---|---|
| Age (years) | 1.09 (1.08 to 1.10) | <0.001 | 1.08 (1.07 to 1.10) | <0.001 |
| Marital status | | | | |
| Single | 1 | | 1 | |
| Married | 3.19 (2.62 to 3.92) | <0.001 | 0.88 (0.67 to 1.16) | 0.350 |
| Educational level | | | | |
| Junior school and below | 1 | | 1 | |
| High and technical school | 0.84 (0.69 to 1.01) | 0.067 | 1.03 (0.79 to 1.34) | 0.830 |
| College and above | 0.48 (0.39 to 0.58) | <0.001 | 0.76 (0.55 to 1.06) | 0.110 |
| Nationality | | | | |
| Non-EU countries | 1 | | 1 | |
| EU countries | 1.16 (0.98 to 1.36) | 0.077 | 0.83 (0.67 to 1.02) | 0.080 |
| Rank group | | | | |
| Officer | 1 | | 1 | |
| Non-officer | 1.30 (1.12 to 1.50) | 0.001 | 1.75 (1.44 to 2.13) | <0.001 |
| Work site | | | | |
| Deck | 1 | | 1 | |
| Engine | 0.74 (0.63 to 0.87) | <0.001 | 0.82 (0.67 to 1.01) | 0.059 |
| Galley | 0.56 (0.42 to 0.73) | <0.001 | 0.52 (0.36 to 0.74) | <0.001 |
| Work experience | | | | |
| <10 years | 1 | | 1 | |
| 10+ years | 5.69 (4.60 to 7.10) | <0.001 | 1.79 (1.33 to 2.42) | <0.001 |
| Working hours per week | 1.03 (1.02 to 1.04) | <0.001 | 1.02 (1.01 to 1.03) | <0.001 |
| Smoking status | | | | |
| No | 1 | | 1 | |
| Yes | 4.29 (3.68 to 5.01) | <0.001 | 5.43 (4.49 to 6.59) | <0.001 |
| Alcohol consumption | | | | |
| No | 1 | | 1 | |
| Yes | 2.95 (2.54 to 3.43) | <0.001 | 2.19 (1.82 to 2.64) | <0.001 |
| Snoring status | | | | |
| No | 1 | | 1 | |
| Yes | 4.84 (4.15 to 5.66) | <0.001 | 3.58 (2.96 to 4.34) | <0.001 |
| BMI | 1.22 (1.19 to 1.25) | <0.001 | 1.12 (1.08 to 1.15) | <0.001 |

*Common confounders adjusted for in the multivariable logistic regression model include age, BMI, working hours per week, marital status, nationality, educational level, rank, work experience, worksite, alcohol use, smoking and snoring status.
BMI, body mass index.

Table 6 Univariable and multivariable analysis of predictors of self-reported

This suggests a positive association between BMI and hypertension. Therefore, as BMI increases, the likelihood of developing hypertension also increases. Regardless of the study method, the results are consistent with other seafarers' studies that showed average blood pressure increases parallel to BMI (World health organization, 2021). In our study, non-officers had 75% higher odds (95% CI 1.44 to 2.13) of having HTN than officers. These findings agree with previously conducted studies among seafarers (Sagaro, 2021). A possible explanation for this could be work-related stress. Non-officers typically work long hours, participate in physically demanding activities and sleep fewer hours (Oldenburg, 2019; Sagaro, 2021). Cigarette smoking was identified as another risk factor in this study. The study found that smoking was one of the most important risk factors for HTN, and smokers had 5.43 (95% CI 5.49 to 6.59) times higher odds of having HTN than non-smokers. Study conducted among Danish seafarers also revealed a high prevalence of hypertension among smokers (Tu, 2016). Another study conducted among

Danish seafarers found that non-officers were more likely than officers to smoke every day (Hjarnoe, 2014). In general, the maritime industry is a hazardous and physically demanding occupation. Consequently, seafarers are more likely to experience unhealthy lifestyles (such as smoking, physical inactivity and inadequate sleep). Seafarers working on ships face unique challenges that are often overlooked. In addition to being sedentary, seafarers are expected to take on high levels of responsibilities, including navigation, planning, loading and unloading, and participation in other duties that occur during the voyage.

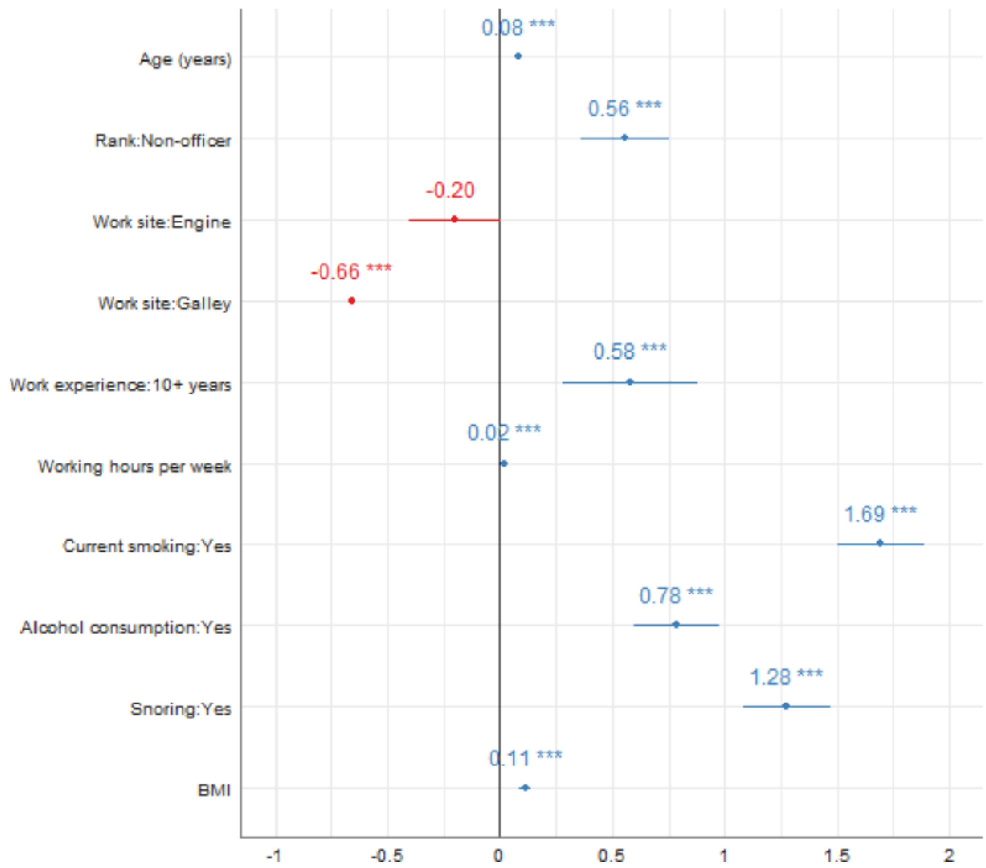


*Figure 4 Forest plot of regression coefficients and their 95% CI for multiple logistic regression analysis of self-reported hypertension among seafarers. ***p<0.001. BMI, body mass index.*

Thus, they suffer from a higher level of work-related stress than workers on land. In a recent study, the responsibilities of employees showed a significant association with the prevalence of smoking and the likelihood that they will smoke (Iolanda, 2020). The results of our study suggest that long working hours per week was an independent risk factor for HTN. With every working hour increase, the odds of reporting hypertension increase by 2.0% (95% CI 1.01 to 1.03). Overall, the average number of working hours per week for all study participants was 65.96±10.98 (for subjects with and without reported hypertension, 68.7±11.2 and 65.3±10.8, respectively, and the difference was also statistically significant).

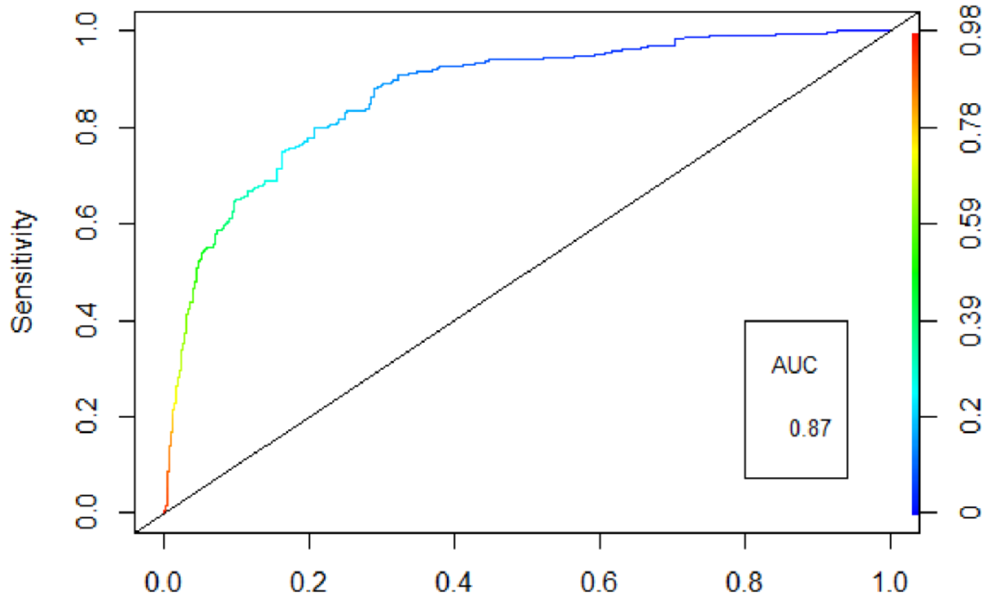


*Figure 5 Receiver operating characteristic (ROC) curve of final a risk prediction model for seafarers with self-reported hypertension.*

This finding is consistent with the study conducted in the general population that reported working hours per week positively associated with and probability of having HTN (Yang, 2006). The same study reported that subjects who worked 40 hours per week were 14% more likely to report hypertension than those who worked 11–39 hours per week (Yang, 2006). We also documented in our previous study that the higher prevalence of HTN (32.2% (95% CI 29.3% to 35.2%)) among seafarers who worked long hours per week (>71 hours per week) (Sagaro, 2021). In contrast, the study conducted among seafarers on German-flagged ships reported that working hours were not significantly associated with coronary risk factors (Oldenburg, 2008). The difference in results could be attributed to methodological differences between the studies. In our study, the outcome variables, along with the majority of variables, were based on self-reported data. On the other hand, the study conducted on the German-flagged ship used data that were not self-reported. In particular, the blood pressure measurements were not self-reported. Instead, the measurements were taken by the healthcare professionals during the study period, which could have introduced some variability in the results.

Other methodological differences exist between the present study and the study conducted on German vessels, including sample size, the method of measuring outcome variables and statistical analysis. According to a study conducted in the general population, the risk of HTN significantly increases with the number of working hours (Yoo, 2014). Long working hours have significant health impacts and can lead to various health problems, including hypertension. To address this issue, telemedicine strategies targeting long working hours could be effective in reducing the risk of reported hypertension among seafarers. The use of telemedicine for healthcare delivery has been gaining popularity over the years, and it offers a convenient and effective way to manage health conditions without the need to physically visit a healthcare provider. Another important independent risk factor that was identified in this analysis was work experience. The study subjects who had 10 years and above of work experience at sea were (AOR=1.79 (95% CI 1.33 to 2.42)) more likely to report hypertension than those who had less than 10 years. This result is consistent with other study conducted among seafarers, which reported work experience at sea (AOR=1.80 (95% CI 1.02 to 1.14)) positively associated with the risk of coronary heart risk factors (Oldenburg, 2008). A study conducted among seafarers documented those participants who had 21 years and above (34.5% (95% CI 31.2% to 37.9%)) of work experience at sea had higher self-reported hypertensin when compared with those who had less than 10 years (6.6% (95% CI 5.5% to 8%)) (Sagaro, 2021). The positive association between work experience and HTN can be attributed to job stress. The study conducted among the general population provides evidence that stressful work environment was a significant predictor of chronic health conditions (Koolhaas, 2014). In response to high levels of stress, the body releases hormones, which cause the heart to beat faster and the blood vessels to narrow, resulting in an increase in blood pressure. Therefore, working for many years in stressful environments could increase the risk of chronic health conditions, including hypertension over time. We found that the worksite on board ships was an independent predictor for HTN. Accordingly, those who worked in the galley room or catering were found to have 48% (AOR=0.52, 95% CI 0.36 to 0.74) lower odds of reporting hypertension compared with those who worked in the deck room. This could be attributed to work-related stress, as deck workers are more prone to sleep interruption, high job demands, night shift work and intense physical activity than engine workers and galley staff (Oldenburg, 2019; Sagaro, 2021). In a study conducted among industrial workers, it was found that work-related stress was associated with hyper- tension (Rengganis, 2020). Our study's findings suggest that work-related stress may play a significant role in the development of hypertension, particularly among workers in high-stress jobs such as those in the deck room. It is important for employers to take steps to reduce work-related stress and promote healthy work environments to prevent the development of hypertension and other related health conditions among seafarers. In this study, we found that alcohol consumption was an independent risk factor for HTN. The study subjects who drank alcohol were (OR=2.19, 95% CI 1.82 to 2.64) more likely to have reported hypertension than those who did not drink alcohol. It is important to note that seafarers face various work-related stresses on board in addition to isolation from their families, which may contribute to their alcohol consumption. The present study found that among seafarers, alcohol consumption prevalence was 39%. The magnitude of alcohol consumption reported in our study was lower than that previously reported in another study, which documented that 79.4% of seafarers drink alcohol while at sea (Gregorio, 2016). However, it is important to note that the prevalence reported in our study may be underestimated due to the use of self-reported data. As the prevalence of alcohol consumption aboard ships was based on self-reports, it is possible that the actual prevalence is higher than what was reported. Despite this limitation, our study provides valuable insights into the patterns of alcohol consumption among seafarers and highlights the need for further research in this area. The International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers convention sets mandatory limits for alcohol consumption, and the 2010 amendments entered into force from January 2012 (STCW, 1978). However, the prevalence of alcohol consumption is still high on-board ships, and individual flag states need to be assessed if they have implemented the limits or not. Consequently, stricter limits should be applied based on the Convention, and further telemedicine intervention is needed to reduce alcohol intake among seafarers.

In the present study, we identified that snoring was a significant risk factor for HTN. Our results showed that compared with the non-snoring subjects, those who snore had 3.58 times (95% CI 2.96 to 4.34) odds of having reported hypertension. Among the study partici- pants, 1255 (29%) snored. Of which, 515 (41%) subjects reported hypertension.

In total, 57.2% of the study subjects with reported hypertension were snoring. This study suggests that snoring may increase the risk of HTN. This might be due to snoring being relevant to increased sympathetic tone and consequent arterial hypertension. Because snoring is one of the major symptoms of obstructive sleep apnea (OSA) syndrome. Studies conducted in the general population have reported that the elevated sympathetic nerve activity, the increase in circulating catecholamines caused by it and the increased sensitivity to vasoconstrictors may be the mechanisms that bind OSA to blood pressure (Kraiczi, 2000; Somers, 1995; Carlson 1993). Therefore, seafarers who snore should pay close attention to their blood pressure levels in order to early detection and prevention.

Regarding the clinical relevance of developing a risk prediction model for telemedicine, seafarers are one of the remote populations that work at sea, hundreds of kilometers from the nearest healthcare facility. There- fore, access to blood pressure monitoring is not as easy as for land workers. Hence, for those unfamiliar with blood pressure measurement or who are not undergoing treatment, the TMAS physicians during the teleconsultation can predict HTN using this model based on the variables used in this study. In order to estimate the risk of HTN, the risk score should be calculated and, to determine it, TMAS healthcare professionals or any other person must enter values for age, rank, working hours per week, work experience at sea, smoking status, alcohol consumption, snoring, worksite and BMI. Based on a person's risk score, the logistic regression equation can be used to estimate the likelihood of reported hypertension. In this study, we used the classification table for the logit model; the predicted probability cut-off point was 0.5. Therefore, if the predicted risk of HTN for the user exceeds the cut- off point, the user should be warned about HTN. In this case, the predicted risk is greater than the cut-off points, which represent the level of reported hypertension risk. An estimate close to one indicates a high level of risk for HTN. For example, if the predicted risk is 0.868 or 86.8%, which is above the cut-off point (0.5) and close to one. Consequently, this subject is very likely to have HTN, and the PPV provides confidence of 72.8%. Therefore, according to predicted risk, the user should be alerted to the reported hypertension if he/she does not know his/her blood pressure measurement.

Finally, we recommend the development of a well-organized epidemiological observatory of the health conditions of seafarers, which would present detailed and up-to-date information on health conditions linked to sociodemographic data, occupational characteristics, behavioral lifestyles as well as other health indicators of the entire at-risk seafarer population aboard ships. These data are essential for determining the risk scores of individual users, guiding interventions for CVD risk factors, especially modifiable risk factors, directing ranking-based interventions and providing health promotion planning and resource allocation. A conceptual framework for the epidemiological observatory of seafarers' health conditions was developed in our previous study (Battineni, 2020), but it has not yet been implemented on a practical basis. It is, therefore, crucial that responsible bodies such as ship- ping companies, international maritime organization, and stakeholders consider the implementation of an epidemiological observatory on the health conditions of seafarers in order to improve the health services on board ships as well as access the epidemiological data to support evidence-based decision making.

First, almost all the data used in the analysis were self- reported by participants, which may have resulted in response/reporting bias, although we applied different procedures and used a standard questionnaire. Second, we were restricted by the design of the study, and its limitations preclude the identification of a causal relationship between HTN and the investigated characteristics. In addition, a potential bias may arise during data collection regarding HTN. While efforts have been made to minimize potential bias and ensure that results are as accurate as possible, it is important to acknowledge that HTN may still be subjected to certain biases, such as recall bias and misclassification bias. These can lead to under- reporting or over-reporting of hypertension, which can impact the study results. Another limitation of the study is that the model achieves a sensitivity value of 0.564. In other words, 56.4% of participants who reported hyper- tension in the dataset were correctly predicted as having hypertension. According to the classification table, the sensitivity score was relatively low, which may be the result of an imbalanced class proportion among the study participants. The class proportion of the study population was imbalanced with the ratio of participants who reported hypertension to participants who did not report hyper- tension being 1:3.8. This imbalance in class proportion may have contributed to the lower sensitivity score. It is important to note that sensitivity is just one measure of a risk model's accuracy and should not be relied on solely. Other measures, such as specificity and PPV, should also be considered. A risk model, for example, has a specificity value of 0.944, meaning that less than 6% of all participants who did not report hypertension were incorrectly predicted as having hypertension. In other words, 94.4% of the participants who did not report hypertension were correctly predicted as not having hypertension. However, the imbalanced class proportion of the study population is a significant factor that needs to be considered when interpreting the sensitivity of the risk model. While this study has limitations, it is the first to develop a risk prediction model for telemedicine of HTN among seafarers.

### 1.2.4 Conclusion

This study has found that variables associated with an increased risk of HTN include age, BMI, working long hours per week, work experience at sea, rank, smoking status, work site, snoring and alcohol consumption. This study was mainly conducted to develop a risk prediction model for the HTN among seafarers in a telemedicine intervention context. The developed risk prediction model can be used to identify seafarers at high risk of HTN. This can enable the appropriate identification of individuals who need preventive interventions and help improve the health and welfare of seafarers. A current predictive model was also discovered to have higher predictive power in distinguishing those with and without hypertension. The built risk prediction model provides an estimated risk value, which can be used by TMAS center doctors or other healthcare providers to predict hypertension during teleconsultations. These findings may be beneficial in furthering our under- standing of the risk factors and providing insights to inform preventive strategies for hypertension. Overall, this study provides valuable insight into the risk factors associated with hypertension and how they can be used to inform preventative strategies. We recommend that users who achieve a higher level of risk be warned early about the risk of hypertension. It is important to note that a risk prediction model for seafarers' hypertension should not be seen as a replacement for direct measurement of seafarers' blood pressure at sea. In other words, while a risk prediction model can provide useful insights and help identify high-risk groups, it is not a substitute for direct measurement of seafarers' blood pressure on vessels.

## *1.3 Correlation between body mass index and blood pressure in seafarers*

### 1.3.1 Introduction

Globally, in 2019, approximately 1.13 billion people have high blood pressure. Of these, nearly 67% are living in low- and middle-income countries (World Health Organization, 2020). In 2015, one in four men and one in five women had hypertension (World Health Organization, 2020). Increased blood pressure is a serious medical condition that significantly increases the risk of cardiovascular diseases (CVD). Furthermore, it is the preventable risk factor for premature deaths worldwide (World Health Organization, 2020). About 54% of strokes and 47% of coronary heart diseases are attributable to high blood pressure (Lawes, 2001). Over 1.9 billion adults aged 18 and over were overweight in 2019, and among them, around 650 million adults were obese (World Health Organization, 2020). Increased body mass index (BMI) is the main risk factor for CVD, diabetes, especially type 2, musculoskeletal disorders, and other chronic diseases such as certain cancers (World Health Organization, 2020). Furthermore, in 2015, elevated BMI values were responsible for over four million deaths worldwide, and of these numbers, approximately 66% were attributed to CVD (Afshin, 2017).

Seafaring is a dangerous occupation (Oldenburg, 2010), characterized by physical and psychological stressors, sudden climate changes (Sagaro, 2020). Workers at sea have high rates of mortality, illness, and injury when compared to the general population (Mulić, 2012). CVD is the leading cause of death onboard ships (Zrinsko, 2016; Alves, 2010; Grappasonni, 2012). Seafarers working and living conditions are characterized by long working hours, a short average of sleep times, night shift works, prolonged isolation from family, and work-related stress (Berg, 2013; Oldenburg, 2019; Spurgeon, 1997). Furthermore, behavioral risk factors such as smoking, an unhealthy diet, physical inactivity, excessive alcohol consumption are highly prevalent among seafarers (Hjarnoe, 2020; Oldenburg, 2008). This heavy consumption of alcohol and smoking could be due to hectic activity and lack of leisure-time onboard.

Several studies have found that nutritional factors, shift work, sleep patterns, work-related stress, and fatigue may play a critical role in increasing coronary heart diseases (CHD) and other metabolic syndromes such as central obesity, glucose intolerance, and hypertension (Oldenburg, 2008). Also, another work reported that work-related stress increased by over 50% of CHD risk (Kivimäki, 2006). High blood pressure (hypertension) remains the most important and well-documented modifiable risk factor for CVD, such as stroke and coronary heart disease (Polonikov, 2012). In contrast, risk factors such as smoking, lack of exercise, alcohol abuse, increased BMI value, and an unhealthy diet can play a vital role in the cause of arterial hypertension (Kannel, 2004; Labarthe, 2002). Health consequences such as high BMI, diabetes, and hypertension (HBP) are frequent consequences of life at sea (Kirkutis, 2004; Tu, 2016)

In general, there are several studies on the relationship between body mass index (BMI) and blood pressure (BP) in general populations (Dua, 2014; Vuvor, 2017; Tesfaye, 2007; Linderman, 2018). The positive association between BMI and BP is well documented (Dua, 2014; Tesfaye, 2007; Mungreiphy, 2011; Ravisankar, 20005). However, this relationship is not studied in seafarers. Some studies have reported the prevalence of high blood pressure and overweight obesity among seafarers. It has been reported that the occurrence of hypertension was 49% among Lithuanian mariners (Kirkutis, 2004), 44.7% among Danish seafarers (Tu, 2013), 49.7% among seafarers in German-flagged ships (Oldenburg, 2008), 19.2% among Iranian seafarers (Baygi, 2016). Furthermore, the prevalence of overweight and obese was 50% and 20% among Danish seafarers (Hjarnoe, 2014), 42.5% and 8.6% among Iranian seafarers (Baygi, 2016), and 40.8% and 11.2% among seafarers in Italian Flagged vessels (Nittari, 2019), respectively.

The aims of this study are 1) to examine the relationship between Body mass index (BMI) and blood pressure in seafarers; 2) to analyze further BMI as a risk factor for high blood pressure (HBP) in seafarers through a modeling approach.

### 1.3.2 Materials and methods

A retrospective study was carried out on 603 seafarer's medical examination records. In Italian flagships, all seafarers are required to undergo medical examination two times per year (every 6 months) due to the rigorous demand for work onboard ships. The medical examination was conducted by the International Radio Medical Center (C.I.R.M.) physicians and other trained health professionals. C.I.R.M. is an Italian Telemedical Maritime Assistance Service (TMAS) Center and is the organization with the largest experience worldwide in terms of the number of patients assisted and various health surveillance activities performed onboard ships. During the medical examination, seafarers undergo an interview with physicians or trained health professionals, physical examination and measurements, and laboratory tests. All medical examination results are recorded in the C.I.R.M. database. For this study, we analyzed 603 seafarer's medical examination records, carried out between 2018 and 2019 on board of Italian Flagships. Data on weight, height, age, sex, rank, blood pressure value, smoking, and physical activity were extracted from the database by the authors of this study.

Blood pressure (BP), height, and body weight measurements were taken by trained health professionals and physicians. In addition to physical measurements, seafarers who are subjected to medical examinations were interviewed information about demographic data such as age, rank, and other necessary information, including smoking habits and physical activity. Physical activity is defined as seafarers involved in vigorous or moderate exercise or engaged in activities such as carrying or lifting heavy loads for at least 10 minutes continuously. The seafarer's blood pressure, as well as other measurements, were recorded and interpreted according to the WHO criteria (39). Regarding blood pressure, subjects were categorized into three groups: normal blood pressure, prehypertensive, and hypertensive. Normal blood pressure was taken as systolic blood pressure (SBP) <120 mmHg and diastolic blood pressure (DBP) <80 mmHg, whereas SBP reading of 120–139 mmHg and/or DBP value of 80–89 mmHg was classified as prehypertensive. Blood pressure values of SBP ≥140 mmHg and/or DBP ≥90 mmHg and/or self-reported use of antihypertensive medication were classified as hypertensive (39). BMI was determined as weight in kilograms (kg) divided by height in meters (m) squared (Weight (kg)/Height (m)2). BMI was also classified according to WHO guideline, underweight (<18.5 kg/m2), normal body weight 18.5–24.99 kg/m2), overweight (25–29.99 kg/m2) and obesity (≥30 kg/m2) (40).

Statistical analysis was carried out by using STATA software version 15. Descriptive statistics such as mean and standard deviation were analyzed to evaluate the mean value of SBP, DBP, BMI, Height, age, and the bodyweight of the participants. Chi-square and independent sample t-tests were performed to determine the differences in the distribution of categorical variables and continuous variables between rank groups. Pearson product-moment correlation was examined to determine the strength of the association between BMI and BP (SBP and DBP). ANOVA (One – way analysis of variance) was employed to determine differences in the mean value of blood pressure (both SBP and DBP) between age groups and BMI categories.

Multinomial logistic regression models were performed to determine the association between the predictor variables and the dependent variable. The dependent variable (blood pressure) was classified into three groups: normal (reference category), prehypertension, and hypertension. Hence, the multinomial regression model compared the probability in the categories of normal vs. prehypertension and normal vs. hypertension and adjusted for age. The independent variables were BMI, rank group, cigarette smoking, and physical activity. A $p < .05$ was considered statistically significant.

### 1.3.3 Results

A total of 603 seafarers underwent a medical examination onboard Italian Flagships. Of these, 44.4% (268) were officers, and the remaining 335 (55.6%) were non- officers. About 28.4% of officers and 41.2% of non-officers were smoked cigarettes, and cigarette smoking levels differed significantly between the rank group ($p$ = .001). Almost 86% (517) of the participants were engaged in any physical exercises. The mean value of height was significantly higher among officers when compared to non-officers. In contrast, average SBP, DBP, and BMI were significantly higher in non-officers than officers. Almost all (98.2%) of the participants were male, and the remaining 1.8% were female (Table 7).

The prevalence of prehypertension (SBP: 120–139 mmHg and/ or DBP: 80–89 mmHg) and hypertension (SBP > = 140 mmHg and/or DBP > = 90 mmHg) was 39% (95% CI: 35–43%) and 16.6% (95% CI: 13.7–19.8%) in individuals, respectively. Overall, high blood pressure was seen in 56% of the participants. Regarding rank distribution, prehypertension found in 34% of officers and 43% of non-officers. Also, hypertension observed in 9% of officers and 22.4% of non-officers. The differences in blood pressure levels between officers and non-officers were statistically significant($X2(2) = 35.48$, $P < .001$).

A significant difference between BMI categories and rank group ($X2\ (2) = 7.54$, $p = .023$) was noticeable. Almost 40% and 9% of the total subjects were overweight and obese, respectively. The high number of non-officers was overweight (42%) and obese (10.5%) compared to officers.

As shown in Figure 6, 46% and 24.7% of overweight seafarers had prehypertension and hypertension, respectively. The maximum percentage of obese study subjects had prehypertension (47%) and hypertension (39%). The differences in blood pressure levels across various BMI categories were statistically significant ($X2(2) = 92.71$, $p < .001$).

Both the average systolic and diastolic blood pressure were lower for the age group less than or equal to 30 y. The highest mean systolic BP was found among the oldest age group (> =51 y), and the differences were also statistically significant. Average diastolic BP increased from the age group <=30 y to 31–40 y and from 41–50 y to >=51 y. The highest mean DBP was found in the age group 31–40 y and significantly differed across the age groups. The mean SBP and DBP increased from normal body weight to obese category. The minimum average value of systolic and diastolic blood pressure was found among normal bodyweight category, and maximum mean systolic and diastolic blood pressure were found in obese category. The differences both in average systolic and diastolic blood pressure between BMI categories were statistically significant (Table 8).

A positive and statistically significant correlation of BMI with both systolic BP and diastolic BP was observed. This study showed that blood pressure increases while increasing BMI. The correlation of BMI with diastolic BP was stronger when compared to systolic BP. Age was also positively and significantly correlated with systolic and diastolic blood pressure. However, the correlation of age with BMI was stronger than with systolic and diastolic BP (Table 9).

The multinomial regression analysis revealed that BMI and rank of seafarers were the significant predictors of high blood pressure. The odds of prehypertension and hypertension were more than eight and sixteen folds among obese individuals. Non-officers had a significantly higher risk of both prehypertension and hypertension compared to the officers. Being physically active and nonsmoker had a lower risk for both prehypertension and hypertension, but not statistically significant. As assessed by blood pressure, those who were overweight were 3.62 and 6.70 times more likely to have prehypertension and hypertension, respectively, than those who were in the normal BMI groups (Table 7).

| Characteristics | Overall | Officer | Non-officer | *P-value |
|---|---|---|---|---|
| Age group (years) | | | | |
| ≤ 30 | 161 | 85 | 76 | 0.082 |
| 31 - 40 | 227 | 96 | 131 | |
| 41-50 | 124 | 48 | 76 | |
| ≥ 51 | 91 | 39 | 52 | |
| Mean age ± S.D (years) | 37.37 ± 10.53 | 36 ± 10.2 | 38.22 ± 10.72 | 0.026 |
| Mean Height ± S.D (cm) | 174.5 ± 8.88 | 175.7 ± 7.88 | 173.54 ± 9.51 | 0.003 |
| Mean Weight ± S.D (kg) | 77.78 ± 11.09 | 77.5 ± 11.56 | 78.04 ± 10.69 | 0.514 |
| Mean BMI (kg/m$^2$) ± S.D | 25.55 ± 3.24 | 25.05 ± 3.14 | 25.94 ± 3.27 | 0.001 |
| Mean SBP ± S.D (mmHg) | 125.91 ± 10.12 | 123.70 ± 10.47 | 127.86 ± 9.48 | <0.001 |
| Mean DBP ± S.D (mmHg) | 83.45 ± 7.48 | 82.41 ± 6.09 | 84.36 ± 8.32 | 0.001 |
| Currently, smoking any tobacco products | | | | |
| Yes | 214 | 76 | 138 | 0.001 |
| No | 389 | 192 | 197 | |
| Engaged in any exercise | | | | |
| Yes | 517 | 224 | 293 | 0.176 |
| No | 86 | 44 | 42 | |

S.D = standard deviation, kg = kilogram, cm = centimeters, mmHg = millimeter of mercury.
SBP = systolic blood pressure, DBP = diastolic blood pressure, m = meters, *P < 0.05 comparing non-officers vs. officers.

Table 7. Characteristics of the study participants (n = 603).

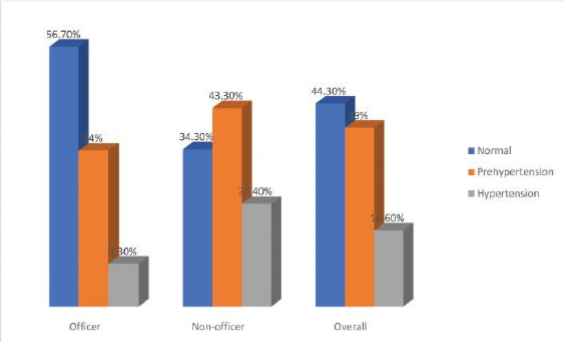


Figure 6. Percentage distribution of blood pressure levels among seafarers by rank group.

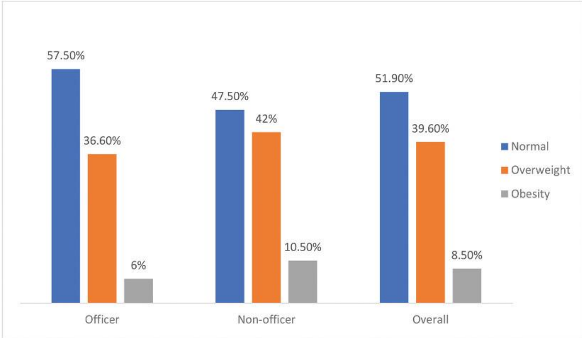


Figure 7. Percentage distribution of body mass index (BMI) levels by seafarer's rank group.

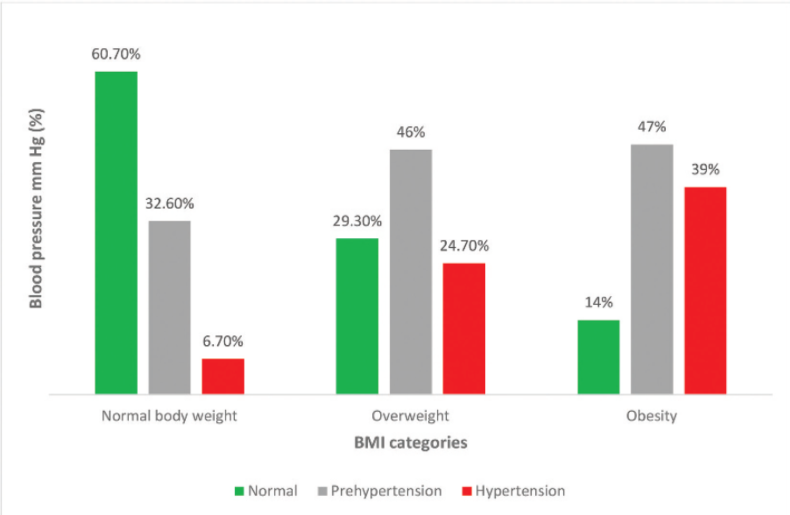


Figure 8. Percentage distribution of blood pressure among seafarers by BMI categories.

| | | Systolic blood pressure (mmHg) | | | | Diastolic blood pressure (mmHg) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Number of participants **n(%)** | Mean score | ±SD | ±SE | F-test | Mean score | ±SD | ±SE | F-test |
| **Age group** | | | | | 4.332** | | | | 4.350*** |
| ≤30 y | 161 (26.7) | 124.33 | 7.97 | 0.63 | | 82.09 | 4.95 | 0.39 | |
| 31–40 y | 227 (37.6) | 126.23 | 9.61 | 0.64 | | 84.49 | 9.02 | 0.59 | |
| 41–50 y | 124 (20.6) | 125.16 | 12.49 | 1.12 | | 82.60 | 7.66 | 0.69 | |
| ≥ 51 y | 91 (15.1) | 128.90 | 10.62 | 1.11 | | 84.42 | 6.24 | 0.65 | |
| **BMI category** | | | | | 58.691*** | | | | 65.773*** |
| Normal | 313 (51.9) | 122.25 | 7.25 | 0.41 | | 80.53 | 4.47 | 0.25 | |
| Overweight | 239 (39.6) | 128.84 | 9.81 | 0.63 | | 85.98 | 8.14 | 0.53 | |
| Obesity | 51 (8.5) | 134.61 | 15.68 | 2.19 | | 89.51 | 10.64 | 1.49 | |

Significant at the **$p < 0.01$, ***$p < 0.001$, F-test: variance-ratio test.

Table 8. Blood pressure among seafarers in different age groups and BMI categories.

| Variables | BMI | Systolic BP | Diastolic BP | Age |
|---|---|---|---|---|
| BMI | 1.00 | 0.336** | 0.344** | 0.313** |
| Systolic blood pressure | 0.336** | 1.00 | 0.640** | 0.174** |
| Diastolic blood pressure | 0.344** | 0.640** | 1.00 | 0.122** |
| Age | 0.313** | 0.174** | 0.122** | 1.00 |

Statistically significant at the **p < 0.01(2-tailed).

Table 9. Correlation matrix between blood pressure, BMI and age in seafarers.

| | Blood Pressure (mmHg) | | | |
|---|---|---|---|---|
| | Prehypertension | | Hypertension | |
| | OR (95% CI) | P- value | OR (95% CI) | P-value |
| BMI category | | | | |
| Normal | 1 | | 1 | |
| Overweight | 3.62 (2.35–5.58)*** | <0.001 | 6.70 (3.74–12.01)*** | <0.001 |
| Obesity | 8.24 (3.59–18.88)*** | <0.001 | 16.75 (6.57–42.73)*** | <0.001 |
| Rank group | | | | |
| Officer | 1 | | 1 | |
| Non-officer | 3.39 (2.21–5.20)*** | <0.001 | 4.83 (2.75–8.46)*** | <0.001 |
| Cigarette smoking | | | | |
| No | 0.98 (0.63–1.52) | 0.925 | 0.80 (0.47–1.37) | 0.153 |
| Yes | 1 | | 1 | |
| Physical activity | | | | |
| No | 1 | | 1 | |
| Yes | 0.87 (0.48–1.59) | 0.657 | 0.78 (0.35–1.74) | 0.540 |

ignificant at the ***P<0.001, the odds ratio was adjusted for age.

Table 10. Determinants of high blood pressure among seafarers estimated with a multinomial logistic regression model (n = 603).

### 1.3.4 Discussion

This study has examined the relationship between BMI and BP, both SBP and DBP among seafarers. As a result, BMI was positively and significantly correlated with both systolic and diastolic blood pressure. However, the relationship between BMI and diastolic blood pressure (r = 0.344) was observed to be stronger than systolic blood pressure (r = 0.336). Besides, a significant positive correlation was observed between age and both SBP and DBP in seafarers, although the correlation coefficients were weak (r = 0.174 (SBP) and r = 0.122 (DBP)). On the other hand, the correlation of age with BMI was found to be stronger than with both systolic and diastolic blood pressure. There is no earlier comparable research regarding the relationship between BMI and BP in seafarers. This study showed that the average BMI, SBP, and DBP were significantly higher among non-officers compared to the officers by rank group ($p < .001$). Mean SBP and DBP increased significantly with age consistently from the younger age groups (≤30 y) to the older age groups (greater than or equal to 51 y) of individuals. This shows that the dependence of blood pressure on the age of seafarers. Similarly, the average systolic and diastolic

BP increased significantly with increasing BMI steadily from healthy body weight to obese category. Thus, mean systolic and diastolic blood pressure increased with increasing BMI levels.

Our study documented that nearly 40% and 9% of the study participants were overweight and obese, respectively. Similar findings were documented in other studies carried out in seafarers (36,38). Our finding was not consistent with the study conducted among Danish sailors, which reported 70.8% overweight (Hansen, 2011). Another study reported 76.6% and 30.9% of overweight and obesity, respectively, among Danish seafarers (Hoeyer, 2005). The rank-specific prevalence of overweight and obesity significantly increased among non-officers compared to officers. This might be due to work-related stress and poor psychological emotions (e.g., depression, anxiety, and negative emotions) because non-officers (deck crew and engine crew) work is characterized by night shift work, long working hours, short average sleep time and often sleep interruptions, and physical stress. Several studies have reported that work- related stress and negative emotions (e.g., negative mood) are risk factors for high BMI (overweight and obesity) by promoting poor health behaviors, such as unhealthy diet, insufficient physical activity, excessive alcohol use, and smoking (Faghri, 2015; Wardle, 2000). Thus, work-related stress contributes to bodyweight gain (Faghri, 2015) and abdominal obesity (Wardle, 2010). We found that a high number of overweight individuals had prehypertension (46%). Furthermore, the maximum percentage of obese subjects in the study had prehypertension (47%) and hypertension (39%). In other words, the prevalence of both prehypertension and hypertension significantly higher in individuals who were overweight and obese than those of healthy bodyweight categories.

This study found a high prevalence of both prehypertension and hypertension among non-officers when compared to officers. Also, the difference between high blood pressure distribution between rank groups was statistically significant ($p$ < .001). In other words, the prevalence of high blood pressure was significantly higher in non-officers (65.7%), with 43% being prehypertensive and 22.4% being hypertensive. This could be due to work stress and hectic activity onboard ships. Officers have high-level responsibilities such as navigation, planning, and control of the ship (STCW, 2020). In contrast, non-officers' jobs are characterized by mooring and unmooring the vessel, loading, and unloading cargo (STCW, 2020; Oldenburg, 2009); hence, non-officers works are physically more demanding and stressful than officer's jobs. Different studies have revealed that job-related stress contributes to the development of coronary heart diseases (CHD) (Cooper, 1976) and metabolic syndromes (Chandola, 2006), such as high blood pressure.

In this study, multinomial logistic regression analysis identified overweight, obesity, and rank of the seafarers as significant determinants of both prehypertension and hypertension. The odds of high blood pressure, both prehypertension, and hypertension more than three and four folds among non- officers compared to officers. The risk of elevated blood pressure is significantly higher among individuals with overweight and obesity categories. In other words, the odds of prehypertension and hypertension were 3.62 and 6.70 times higher among individuals who were overweight compared to the normal bodyweight categories. Similarly, the odds of prehypertension among those in obesity categories were 8.24 times higher than individuals in healthy bodyweight categories. The risk of hypertension was significantly highest among individuals in the obesity groups (OR = 16.70, 95% CI: 6.57–42.73; $p < .001$) compared to those who were in the healthy bodyweight categories. Being physically active and not smoking had a lower risk of hypertension, although the difference was not statistically significant. Our work was limited by the use of retrospective data, and we did not have some important variables such as dietary variables, which could be potential confounders or mediators for the observed associations. Additionally, we did not consider information on antihypertensive medication due to a lack of information in the datasets. However, our work is the first to examine the relationship between BMI and blood pressure in seafarers.

### *1.3.5 Conclusion*

The present study showed a positive and significant relationship between BMI and blood pressure. There were significant positive correlations between BMI, age, SBP, and DBP, although the magnitude of the correlation differed. Our work documented a significantly high prevalence of prehypertension among overweight and obese seafarers. Furthermore, overweight and obesity are strong predictors for high blood pressure, both prehypertension and hypertension in seafarers. The risk of high blood pressure was highest among individuals who were obese. In other words, blood pressure increases while increasing BMI levels. Hence, attention should be given on weight management program in relation to the prevention and control of high blood pressure. Seafarer health interventions targeting to reduce BMI would have significant effects in reducing the burden of high blood pressure on board ships.

### 1.4 Conclusions

The evidence presented in the first chapter highlights several key findings regarding cardiovascular disease (CVD) and hypertension among merchant seafarers:

CVD Diagnosis Disparity: Non-officers were diagnosed with CVD more frequently than officers, with officers often diagnosed with hypertensive CVDs and non-officers with ischemic heart diseases (IHDs).

Age as a risk Factor: Older seafarers aged 51 to 60 showed a higher frequency of CVD diagnosis, emphasizing the importance of targeting interventions towards this age group.

BMI and Blood Pressure Correlation: The study documented a significant positive relationship between body mass index (BMI) and blood pressure, with overweight and obesity strongly predicting high blood pressure among seafarers.

Risk Prediction Model for Hypertension: A risk prediction model was developed to identify seafarers at high risk of hypertension, incorporating variables such as age, BMI, work hours, experience at sea, rank, smoking status, and alcohol consumption. This model can aid in early identification of individuals needing preventive interventions, potentially improving seafarers' health and welfare.

Recommendations and Preventive Measures: Effective prevention measures are crucial to mitigate the burden of CVD on merchant seafarers. These include early diagnosis, regular follow-up, crew training in basic life support and defibrillator use, and the introduction of telemonitoring equipment for cardiovascular diagnosis via telemedicine. Recommendations include early warnings for those at higher risk of hypertension, though it's emphasized that the risk prediction model should complement, not replace, direct measurement of blood pressure at sea

In summary, the evidence underscores the importance of targeted interventions, regular health monitoring, and the development of predictive tools to combat CVD and hypertension among merchant seafarers.

# Chapter two: An epidemiological analysis of musculoskeletal systems diseases among seafarers

This chapter aims to address these concerns by presenting a comprehensive examination of musculoskeletal system diseases among seafarers from an epidemiological perspective. Through the presentation of new findings, we seek to achieve the following objectives:

1. To provide an overview of the epidemiological aspects of musculoskeletal disorders within the seafaring community.
2. To assess the prevalence of musculoskeletal diseases among seafarers and identify patterns related to age, rank, and years at sea.
3. To explore potential risk factors associated with the development of musculoskeletal disorders in this occupational group.
4. To discuss the implications of these findings on the health and safety of seafarers and propose recommendations for future research and interventions.

In the following sections, we will delve into an in-depth exploration of this pressing issue, utilizing epidemiological methodologies to shed light on the prevalence, risk factors, and impacts of musculoskeletal system diseases among seafarers. This chapter aims to contribute valuable insights to the maritime community, occupational health professionals, and policymakers for the betterment of seafarers' working conditions and overall well-being.

## 2.1 Diseases of the musculoskeletal system and connective tissue among seafarer

An epidemiological analysis was conducted to identify the most prevalent causes of illness onboard Italian vessels and to evaluate the frequency of injuries among seafarers to develop prevention strategies. The Centro Internazionale Radio Medico (C.I.R.M.) database is main data sources. In the C.I.R.M. database, seafarers' diseases and injuries were categorized according to the International Classification of Diseases, 10th Revised Version (ICD10) of the World Health Organization (WHO). Occupational diseases and injuries were classified based on prompt diagnoses and medical records stored in the C.I.R.M. database. Any contact for medical requests from ships to the C.I.R.M. Identifies injuries or illnesses with relevant patient information, such as age, gender, occupation, rank, nationality, ship flag, ship name, date of the medical event, anatomical location of the injury, diagnosis, treatment provided, follow-up schedule for the patient, and other pertinent information. Hence, we got access to occupational injuries and diseases with seafarers' age, nationality, rank, diagnosis, and worksites from the TMAS database for this preliminary analysis.

Diseases of the musculoskeletal system and connective tissues were recorded and coded according to the International Classification of Diseases 10th revised version (ICD 10) in the C.I.R.M. database. In accordance with ICD 10, the codes M00 - M99 were assigned to diseases of the musculoskeletal system and connective tissue. ICD 10 classifies disorders of the musculoskeletal system and connective tissue into main groups. Consequently, the musculoskeletal system and connective tissue disorders can be classified as arthropathies (M00 - M25), systemic connective tissue disorders (M30 - M36), dorsopathies (M40 - M54), soft tissue disorders (M60 - M79), osteopathies and chondropathies (M80 - M94), as well as other musculoskeletal and connective tissue disorders (M95 - M99).

In the period 2010 to 2022, 320 (8.35% of all pathologies assisted) disorders of the musculoskeletal system and connective tissues were treated onboard Italian ships. Seafarers with musculoskeletal and connective tissue disorders were on average 39.78 + 11.23 years old (range: 19 to 68 years old). Seafarers aged 30 to 40 years were frequently contacted for disorders of musculoskeletal and connective tissue (34.69% of all seafarers received telemedical consultation due to musculoskeletal and connective tissue disorders). Engine officers (23.75%) were frequently diagnosed with musculoskeletal and connective tissue disorders compared to deck officers (18.75%). In terms of the work sites, 43.44%, 40.94%, and 15.63% of the engine room, deck, and galley workers were contacted for musculoskeletal and connective tissue disorders between 2010 and 2022. According to our analysis, 38.44%, 31.56%, 19.69%, and 5.94% of the seafarers contacted for disorders of the musculoskeletal and connective tissues were Indian, Italian, Filipino, and Romanian seafarers, respectively. An Italian TMAS assisted a higher number of musculoskeletal and connective tissue cases in 2021 (12.50% of all cases handled between 2010 and 2022 onboard Italian ships). The number of assisted cases of musculoskeletal and connective tissue steadily increased from 4.06% in 2016 to 12.50% in 2021. Similarly, the number of cases increased from 3.75% in 2010 to 10.00% in 2013. Between 2010 and 2022, low back pain, lumboischialgia (sciatica), tendonitis, cervicalgia, arthritis, unspecified, and other joint disorders were the most common diagnosis of musculoskeletal and connective tissue disorders onboard Italian ships.

## 2.2 An epidemiological analysis of low back pain among seafarers

### 2.2.1 Introduction

Low back pain is a common disorder involving the lumbo-sacral region of the back (National Institutes of Health, 2003). Lumbo-sacral pain results from injury to muscles, ligaments, joints, or discs. There are other conditions that can cause low back pain, including: cancer of the spinal cord, ruptured or herniated discs, sciatica, arthritis, and kidney infections (Manek, 2005). In developed countries, 70/80% of the general population will experience low back pain at some point in their lifetime (Furlan, 2002). It is estimated that the prevalence rate for adolescents is 10-20%, which is lower than that seen in adults but is still rising (O'Sullivan, 2019). In the world, low back pain is the sixth most common cause of activity limitation, the second most common reason physicians' visits, and the leading cause of disability (Hoy, 2014; Global Burden of Disease Study, 2013). There are several causes of low back pain, including slipped discs, hernias and spondylolisthesis, muscle and soft tissue injuries, where physical and psychological factors in the work place may increase the risk of low back disorders or accelerate existing changes (Floren, 1997). The prevalence of low back pain is higher in jobs such as nursing, driving, and laboring due to frequent changes in posture, lifting heavy loads, bending, and lifting objects (Forouzanfar, 2013). Work-related risk factors can somehow play a role in causing low back pain. Numerous studies have identified several factors associated with low back pain (Floren, 1997). Among these are: working long hours at a computer station is frequently linked to back and neck pain (Ortiz, 2003). Significantly contribute to the development of muscle and joint problems can be caused or made worse by poor workstation design (Lis, 2007; Spyropoulos, 2007). Additionally, a poor prolongated sitting position may even result in low back pain (Lis, 2007; Spyropoulos P, 2007). Lifting and carrying objects repeatedly (Gawde NC, 2018), poor posture, and awkward sleeping habits (Parmar, 2017) have also been linked to low back pain. Moreover, psychological factors such as stress (Yip, 2001), low social support (Clays, 2007), and low job satisfaction (Lis, 2007; Spyropoulos, 2007) have been linked to low back pain. Low back pain may cause occupational disabilities, increased costs of care and treatment, loss of productivity, and absence from work (Leggat, 2007). In the maritime industry, diseases of the musculoskeletal system are identified as one of the most common complaints, accounting for an estimated 6-8 percent of the total cases reported to Maritime Telemedical Assistance Service (Mahdi, 2016). While numerous studies have been conducted on the prevalence and associated factors of back pain among different groups of workers, no study has been conducted on seafarers. Hence, the purpose of this study was to determine the prevalence and defining characteristics of low back pain among seafarers.

### 2.2.2 Materials and methods

Based on a retrospective design, we collected data from the Centro Internazionale Radio Medico (International Radio Medical Center, C.I.R.M) database. C.I.R.M. is the Italian Telemedical Maritime Assistance Service (T.M.A.S.) and represents one of the oldest and best known T.M.A.S. worldwide. C.I.R.M. operates since 1935 and has assisted more than 100,000 seafarers on board ships (Mahdi, 2016). Data regarding requests for medical assistance received by the Telemedical Maritime Assistance Service (TMAS) of the C.I.R.M. in the years 2015-2021 were collected from C.I.R.M. database and musculo-skeletal cases were identified. Among them, low back pain cases were identified and extracted. Descriptive analysis of seafarer's demographic variables, including age, rank, and worksite, was done to evaluate the distribution of diseases. Rank was stratified by officers (deck and engine officers) and non-officers (deck and engine ratings, and galley). Worksite was also categorized into three groups, including the deck, engine, and galley. Diagnosis of C.I.R.M. physicians was classified according to the International Classification of Diseases ICD-10 (WHO, 2007). ICD-10 is the International Classification of Diagnoses. This standard is used worldwide for general epidemiology, health management and clinical analysis. Patients were divided by their age in four group: Young (age < 18); Young adults (age 18-35); Middle - aged adults (age 36-55); Adults (age > 55). These data were then analyzed statistically according to the basic standards of epidemiology. Before using the analysis of variance, the assumptions of normality were verified. Statistical significance was set at $p < 0.05$. A one-way analysis of variance (ANOVA) was used to test the differences between the three macro weight categories and between rounds. When a significant F value was found, Bonferroni's post-hoc tests were applied. Effect size (ES) in the analysis of variance (ANOVA) was computed as $\omega^2$, to assess the meaningfulness of differences, with $\omega^2 < 0.01$, $0.01 < \omega^2 < 0.06$, $0.06 < \omega^2 < 0.14$, and $\omega^2 > 0.14$, as trivial, small, moderate, and large ES, respectively.

| ICD-10 CODE | 2015 | | 2016 | | 2017 | | 2018 | | 2019 | | 2020 | | 2021 | | Total | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No | % | No | % | No | % | No | % | No | % | No | % | No | % | No | No | % |
| Diseases of the musculoskeletal system and connective tissue | 294 | **6.78*** | 316 | **6.62*** | 355 | **6.97*** | 327 | **6.38*** | 485 | **8.54*** | 863 | **12.3*** | 904 | **12.1*** | 3,544 | 506.28 | **8.5*** |
| Low back pain | 140 | **47.6**** | 138 | **43.7**** | 165 | **46.5**** | 166 | **50.8**** | 208 | **42.9**** | 346 | **40.1**** | 352 | **38.9**** | 1,515 | 216.4 | **44.3**** |

Table 11. Diseases of the musculoskeletal system and Low back pain pain assisted from C.I.R.M. in the years under analysis
***** percentage of total cases assisted by C.I.R.M.
****** percentage of total Diseases of the musculoskeletal system and connective tissue assisted by C.I.R.M.

| **Rank** | **2015** | | **2016** | | **2017** | | **2018** | | **2019** | | **2020** | | **2021** | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **No** | **%** | **No** | **%** | **No** | **%** | **No** | **%** | **No** | **%** | **No** | **%** | **No** | **%** | **No** | **%** |
| Deck Officer | 31 | 22.1 | 23 | 16.7 | 25 | 15.2 | 39 | 23.5 | 36 | 17.3 | 69 | 19.9 | 65 | 18.5 | 288 | 19.0 |
| Deck Rating | 34 | 24.3 | 36 | 26.1 | 61 | 37.0 | 46 | 27.7 | 74 | 35.6 | 89 | 25.7 | 93 | 26.4 | 433 | 28.6 |
| Engine Officer | 27 | 19.3 | 31 | 22.5 | 28 | 17.0 | 33 | 19.9 | 37 | 17.8 | 81 | 23.4 | 76 | 21.6 | 313 | 20.7 |
| Engine Rating | 39 | 27.9 | 38 | 27.5 | 43 | 26.1 | 36 | 21.7 | 48 | 23.1 | 76 | 22.0 | 90 | 25.6 | 370 | 24.4 |
| Galley Staff | 9 | 6.4 | 10 | 7.2 | 8 | 4.8 | 12 | 7.2 | 13 | 6.3 | 31 | 9.0 | 28 | 8.0 | 111 | 7.3 |
| Total case | 140 | 100 | 138 | 100 | 165 | 100 | 166 | 100 | 208 | 100 | 346 | 100 | 352 | 100 | 1,515 | 100 |

Table 12. Low back pain among rank group

| **Age group** | **Deck Rating** | | **Deck Off** | | **Engine Rating** | | **Engine Off** | | **Galley** | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **No** | **%** | **No** | **%** | **No** | **%** | **No** | **%** | **No** | **%** | **No** | **%** |
| >25 | 63 | 14.5 | 36 | 12.5 | 51 | 13.8 | 43 | 13.7 | 16 | 14.4 | 209 | 13.8 |
| 25-35 | 157 | 36.3 | 94 | 32.6 | 130 | 35.1 | 111 | 35.5 | 35 | 31.5 | 527 | 34.8 |
| 36-45 | 119 | 27.5 | 77 | 26.7 | 105 | 28.4 | 79 | 25.2 | 28 | 25.2 | 408 | 26.9 |
| 46-55 | 54 | 12.5 | 46 | 16.0 | 50 | 13.5 | 47 | 15.0 | 18 | 16.2 | 215 | 14.2 |
| >55 | 40 | 9.2 | 35 | 12.2 | 34 | 9.2 | 33 | 10.5 | 14 | 12.6 | 156 | 10.3 |
| | **433** | | **288** | | **370** | | **313** | | **111** | | **1515** | |

Table 13. Low back pain between age group among rank on board

| OUTCOME | 2015 | | 2016 | | 2017 | | 2018 | | 2019 | | 2020 | | 2021 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No | % | No | % | No | % | No | % | No | % | No | % | No | % | No | % |
| (Medevac/ Diversion) | 1 | 0.7 | 0 | 0.0 | 1 | 0.6 | 2 | 1.2 | 1 | 0.48 | 3 | 0.87 | 2 | 0.57 | 10 | 0.66 |
| Treated On Board | 31 | 22.1 | 26 | 18.8 | 42 | 25.5 | 52 | 31.3 | 53 | 25.48 | 96 | 27.75 | 93 | 26.42 | 393 | 25.94 |
| Visited Ashore On Port Of Call (No Diversion) | 105 | 75.0 | 106 | 76.8 | 118 | 71.5 | 111 | 66.9 | 145 | 69.71 | 231 | 66.76 | 243 | 69.03 | 1059 | 69.90 |
| No Informations | 3 | 2.1 | 6 | 4.3 | 4 | 2.4 | 1 | 0.6 | 9 | 4.33 | 16 | 4.62 | 14 | 3.98 | 53 | 3.50 |
| | 140 | 100 | 138 | 100 | 165 | 100 | 166 | 100 | 208 | 100 | 346 | 100 | 352 | 100 | 1,515 | 100 |

Table 14. Outcome of medical assistance

### 2.2.3 Results

This epidemiological study was conducted from January 1st 2015 to December 31st 2021 at the Centro Internazionale Radio Medico Foundation in Italy. Analysis was made by reviewing 40,179 files of patients assisted by C.I.R.M. from the years under analysis. The analysis involved 1,515 patient who asked medical advice for Low Back Pain at C.I.R.M., for each patient assisted, an electronic medical file is established by C.I.R.M. doctors and updated following every radio contact. Analysis included 1,515 medical records. Examining Low Back Pain in the last 5 years (Table 11), 140 patients were assisted in 2015, 138 in 2016, 165 in 2017, 166 in 2018, 208 in 2019, 346 in 2020, and 352 in 2021. All seafarers examined were male, aged between 18 and 66 years (mean 39.00 ± 11.38 years). As per rank group, 288 (19.0%) of them were Deck Officer; 433 (28.6%) Deck Rating; 313 (20.7%) were Engine Officer; 370 (24.4%) Engine Rating; and 111 (7.3%) Galley staff. Among 1,515 cases received, more than 55% were unlicensed seafarer (Table 12). Concerning age groups, 209 (13.8%) cases involved in young patients (age < 25); 527 (34.8%) patients were in the age group 25-35; 408 (26.9%) patients were in the age group 36-45; 215 (14.2%) patients were in the age group 46-55; 156 (10.3%) patients had more than 55 years (Table 13). Regarding outcome 393 (25.9%) patients received treatment and fully recovered on board, 1059 (69.9%) patients were visited ashore on port of call. Diversions of ship occurs just in the 0.6% of cases (Table 13).

Significant main effects of rank on board were found in total days of low back pain in seafarers ($F_{4,1515}$ = 7.73; p= < 0,005; $\omega^2$=0,32), disease was longer in Deck Rating comparing to Deck Officer (p: 0.02); Galley Staff (p: 0.0004); and Engine Officer (p: 0.001). Also, disease was longer in Engine Rating comparing to Galley Staff (p: 0.03). No effect of age was found in Low Back Pain between rank on board ($F_{4,818} = 0.6$; p= > 0,5; $\omega^2 = 0$).

### 2.2.4 Discussion

Based on data from the Centro Internazionale Radio Medico database, this study examines Low Back Pain disorders among seafarers over the last four years. Our study results indicate that Low Back Pain disorders are frequent pathologies aboard ships. It should be noted that Low back pain disorders are significantly more common among the musculoskeletal disorders, accounting for 45% of all diseases of the musculoskeletal system and connective tissue treated by C.I.R.M during the period 2015-2021. Seafarers are a population at high risk of developing several diseases (Pukkala, 2009). In the case of these workers, the ship is not just a working area, but a residence for quite a long time (Nittari, 2016). There have been several studies showing that obesity, overweight, and a lack of physical activity are common health problems in seafarers (Nas, 2014; Hansen, 2011).

| Rank on board | Mean Days (SD) | Mean age (SD) |
|---|---|---|
| Deck Rating | 9.4±2,8 * + ¥ | 36,3±10.9 |
| Deck Off | 8.3±3,2 Ώ | 38,03±11.8 |
| Engine Rating | 9.0±2,7 + | 36,8±10.7 |
| Engine Off | 8.0±2,6 Ώ | 37,1±11.5 |
| Galley | 7.9±2,2 Ώ ʘ | 38,1±11.5 |
| Mean | 8.5±2,7 | 37,06±11.3 |
| DF | F 0.6 4 211 | F 7.7 4 818 |

Table 15. Charecteristics of low back pain among rank on board

* Significantly different comparing to Deck Off (p<0,05); Ώ Significantly different comparing to Deck Rating (p<0,05); ¥ Significantly different comparing to Engine Off (p<0,05); ʘ Significantly different comparing to Engine Rating (p<0,05); + Significantly different comparing to Galley Staff (p<0,05).

These factors can increase the risk of musculoskeletal diseases. In addition, several risk factors such as whole-body vibrations, ergonomic strain, monotonous work, and poor supervisor-employee relationships can increase the risk of developing low back pain (Ekpenyong, 2014). There was a significant difference in the duration of diseases among rank groups. A low back injury forced Deck Rating seafarers to miss work on average for nine days, more than any other group of seafarers. According to previous research, patients with Low Back Pain (LBP) will recover within 1 month, but they may experience recurrence or prolonged pain. (Pengel, 2003). Approximately 90% of patients with low back pain recover within two weeks (Coste, 1994). In addition, approximately 6% to 10% of patients develop chronic low back pain (Croft, 1998). Considering this point of view, although our study does not present follow up data, the differences discovered in rank groups indicate that job loads may vary considerably across different types of work on board. This might be due to the repetitive nature of their work. There is also a possibility that certain working positions lead to back strain, particularly when poor ergonomics are involved and the respondents are working at a moving desk. In this regard, further studies are needed. The findings presented here provide new information that can be utilized for developing specific rank-related prevention strategies. In the data, it can be seen that a majority of low back pain issues occur between the ages of 25 and 45. Our results are in contrast with other studies, which shows that Low back Pain problems increases with age (Bressler, 1999). It is likely that younger seafarers perform more repetitive tasks than older seafarers who are usually engaged in supervisory duties. Several important strengths can be identified in this study. The large dataset with a high number of cases was likely indicative of conditions that commonly affect seafarers. It is important to note that this study has some limitations: because there was no information on the population at risk, prevalence- and incidence risks could not be estimated. Still the description of the characteristics is useful to starting point out some main areas for health promotion. In order to estimate relative risks, a denominator-based epidemiological study is necessary in order to determine relative risks, which is not possible without denominators. In addition, the efficiency of the work environment is among the most important factors, as half of the respondents agreed that their workplace was poorly organized. At home, people are able to rest more and to be physically active, leading to a wider range of activities using their bodies. Focused exercise, ergonomic improvements in workplaces and more job variation on board seem to be necessary measures (Geving, 2007). Exercise with a focus on form and function, ergonomic improvements in the workplace, and more variety in the work environment are recommended (Geving, 2007).

### 2.3 Conclusions

The study acknowledges its reliance on the C.I.R.M database, which provides a rich dataset but lacks information on population at risk, limiting the estimation of prevalence and incidence rates. Nevertheless, the study's detailed characterization of LBP among seafarers lays the groundwork for future research and preventive interventions. The findings underscore the importance of targeted preventive strategies tailored to specific rank-related risk factors. Recommendations include focused exercises, ergonomic improvements in the workplace, and diversification of job tasks to reduce the incidence and impact of LBP among seafarers.

# Chapter three: Analysis of work-activity among seafarers

Seafaring, a profession rooted in centuries of maritime tradition, demands not only mastery of navigation but also a profound understanding of the physical demands inherent to life at sea. In this chapter, we delve into the intricate tapestry of the seafarer's work life, focusing on the meticulous examination of work hours and the exertion required in their daily tasks. Through the lens of time-motion analysis, we aim to unravel the complexities of their physical work-activity, shedding light on the nuances of labor at sea. The maritime industry stands as a testament to human resilience and adaptability, with seafarers navigating the vast expanse of the world's oceans, braving unpredictable weather conditions and confronting formidable challenges with unwavering determination. Yet, amidst the grandeur of the open sea lies a realm where physical exertion intertwines with professional duty, shaping the daily experiences of those who call the ocean their workplace. Understanding the rhythm of work hours is essential not only for optimizing productivity but also for safeguarding the health and well-being of seafarers. By scrutinizing their tasks through time-motion analysis, we aim to dissect the intricacies of their labor, discerning patterns, and identifying areas of potential improvement. From the arduous tasks of deck maintenance to the meticulous precision required in navigation, every aspect of the seafarer's work contributes to the seamless operation of maritime vessels. As we embark on this journey of analysis, we recognize the invaluable contribution of seafarers to global trade and commerce. Their dedication fuels the engine of maritime transport, facilitating the movement of goods and connecting nations across continents. It is incumbent upon us to delve into the depths of their work-activity, acknowledging the challenges they face and striving to enhance their working conditions for the betterment of all. In the pages that follow, we unravel the intricacies of physical work-activity among seafarers, exploring the intersection of labor, time, and motion on the high seas. Through meticulous observation and rigorous analysis, we endeavor to illuminate the path towards a more sustainable and equitable maritime industry, where the welfare of seafarers remains paramount amidst the relentless tides of global commerce. The work demands experienced by seafarers encompass an intricate web of factors, from the hours spent working and resting to the physical work activities performed on board. This chapter delves into the multifaceted nature of seafarers' work demands with a primary focus on three key aspects:

**Working and Rest Hours**: Seafarers' lives are dictated by a strict and often relentless schedule. The allocation of working and rest hours plays a pivotal role in their overall well-being and job performance. Understanding the dynamics of these hours is essential to mitigate fatigue, enhance alertness, and ensure that seafarers can respond effectively to the dynamic and often high-stakes situations they encounter.

**Physical Workload**: The nature of seafaring duties can be physically demanding. Seafarers are frequently required to handle heavy loads, work in challenging weather conditions, and perform tasks that demand a high degree of physical fitness. This chapter explores the physical workload faced by seafarers, emphasizing the importance of optimizing their physical well-being to ensure the safety of maritime operations.

**Physical Work-Activity Performed on Board**: Seafaring is a diverse profession, encompassing a wide array of job roles and activities. This chapter investigates the variety of physical work activities performed on board, from deck operations to engine room maintenance. By understanding the unique physical demands of each role, we can better tailor strategies for enhancing seafarers' well-being and productivity.

### 3.1 Survey of working hours and physical work-activity performed on board

This paper presents the findings of a comprehensive survey conducted to investigate the working and rest hours of seafarers, a vital yet often understudied segment of the global workforce. Seafarers play a critical role in the international shipping industry, ensuring the movement of goods across the world's oceans. However, the nature of their work exposes them to unique challenges related to long working hours, irregular schedules, and the need for adequate rest. This survey explores these challenges, assesses the impact on seafarers' well-being, and highlights potential areas for improvement in working and rest hours regulations and practices.

#### 3.1.1 Introduction

Seafarers constitute a crucial component of the global maritime industry, playing a pivotal role in facilitating international trade and commerce. Despite their significant contribution, seafarers often face arduous working conditions, including long working hours, irregular schedules, and extended periods away from their families (Carotenuto, 2012; Allen, 2008). To address these issues, various international regulations have been put in place, including the Maritime Labour Convention (MLC) of 2006, which sets standards for working and rest hours for seafarers (International Maritime Organization, London 2001). Numerous surveys in the field of workplace time utilization encompass inquiries into employees' working hours. Both questionnaires and diaries serve as data collection tools, but our focus in this article centers on questionnaires.

Researchers encounter a multitude of methodological choices when seeking to gather information from employees about their work hours. As far back as 1962, during the Tenth International Conference of Labour Statisticians, it was noted that the various approaches to querying working hours led to significant heterogeneity in the data. This issue was addressed by providing guidelines to enhance the international comparability of working hour data. Nevertheless, even four decades later, the measurement of working hours in labor force surveys and similar large-scale investigations continues to pose methodological challenges. Among these challenges, the lack of consistency in measuring the number of hours worked is a prominent concern, as highlighted by Bruyère and Chagny (2002).

On the 1st of October 1998, the Working Time Regulations were implemented in the United Kingdom. A pivotal component of this legislation is the imposition of a 48-hour weekly limit on the hours that an employee can be obligated to work. To be more precise, the Working Time Regulations establish a maximum 48-hour workweek, which is averaged over a default reference period of 17 weeks. In certain special circumstances, the reference period can be extended to 26 weeks, or even up to 52 weeks through a collective agreement involving a labor union or the workforce. Notably, the regulations provide an option for workers to voluntarily exempt themselves from the working time limit by entering into a written agreement to that effect. The possibility of opting out in this manner is subject to a review by the European Commission, slated for November 2003.

This survey aims to assess the effectiveness of these regulations and explore the lived experiences of seafarers with regards to their working and rest hours. It investigates the impact of these working conditions on seafarers' health, well-being, and job satisfaction, and identifies potential areas for improvement in existing regulations and industry practices.

### 3.1.2 Materials and Method

The questionnaire was designed for the Google survey tool (Google Forms) and the link shared to the Centro Internazionale Radio Medico (C.I.R.M.). Seafarers were recruited through International Radio Medical Center (C.I.R.M.). C.I.R.M. is an Italian Telemedical Maritime Assistance Service (TMAS) Center and is non-profitable organization with the largest experience worldwide in terms of the number of patients assisted onboard ships. C.I.R.M. provides teleconsultations and medical advice to seafarers and passengers regardless of their nationality and flag of the vessels 24 hours a day, seven days a week, and 365/366 days a year. Data were collected using a standardized and anonymous questionnaire, and the tool has four core parts. The first part of the questionnaire contains the socio-demographic information included age, gender, educational status, nationality, and marital status. The second section of the questionnaire was occupational characteristics, including rank, worksite, job duration at sea, working hours per day, working hours per week, e vigorous-intensity activity at work. Chi-square or Fisher's exact test was used to analyze distributional differences in rank and worksite groups.

### 3.1.3 Results

According to the survey conducted between November and December 2020, there were 8,125 seafarers over 18 on 400 vessels. 4,648 seafarers volunteered to participate in the survey, with a response rate of 57.2%. A total of 330 participants were excluded due to missing information. Therefore, 4318 subjects were included in the analysis. Out of 4318 participants, 44.7% were officers and 55.3% were non-officers, respectively, as shown in Table 16. The mean age of the participants was 37.94 $\pm$ 10.32 (range: 19 – 70 years). Almost all (99.4%) participants were male, and more than seventy percent were from non-EU countries. Of the 3,069 participants from non-EU countries, 58.7% and 36.7% were Filipino and Indian, respectively. More than three-fifths (69.8%) of study subjects were married, and 55.55% were deck workers. The average working hours per week was 65.96 $\pm$ 10.96. 35.5% and 7.9% of officers and 38.7% and 8.6% of non-officers were overweight and obese, respectively. 71.5% of officers and 53.3% of non-officers respectively had a high and middle level of education. Besides, 45.6% of the study subjects had 10 to 20 years job duration at sea.

| Variables | Total (%) | Rank | |
|---|---|---|---|
| | | Officer, n (%) | Non-officer n (%) |
| Number, n (%) | 4318 (100.0) | 1929 (44.7) | 2389 (55.3) |
| Age (in years), mean (SD) | 37.94 + 10.32 | 38.39 + 9.89 | 37.58 + 10.60 |
| Gender (male) | 4290 (99.4) | 1925 (99.8) | 2365 (98.9) |
| Nationality | | | |
| EU-countries | 1222 (28.3) | 782 (40.5) | 440 (18.4) |
| Non-EU countries | 3096 (71.7) | 1147 (59.5) | 1949 (81.6) |
| Marital status | | | |
| Single | 1303 (30.2) | 526 (27.3) | 777 (32.5) |
| Married | 3015 (69.8) | 1403 (72,7) | 1612 (67.5) |
| Educational level | | | |
| Higher | 1741 (40.3) | 1375 (71.3) | 366 (15.3) |
| Middle | 1803 (41.7) | 530 (27.5) | 1273 (53.3) |
| Low | 774 (18) | 24 (1.2) | 750 (31.4) |
| Worksite | | | |
| Deck | 2396 (55.5) | 1167 (60.5) | 1229 (51.4) |
| Engine | 1468 (34) | 762 (39.5) | 706 (29.6) |

| | | | |
|---|---|---|---|
| Galley | 454 (10.5) | 0 (0) | 454 (19) |
| Job duration at sea<br>< 10 years<br>10 – 20 years<br>21+ years | <br>1551 (35.9)<br>1967 (45.6)<br>800 (18.5) | <br>481 (24.9)<br>1000 (40.4)<br>448 (14.7) | <br>1070 (44.8)<br>967 (40.5)<br>352 (14.7) |
| Body mass index (BMI)<br>Underweight<br>Normal<br>Overweight<br>Obesity | <br>34 (0.8%)<br>2355 (54.5%)<br>1571 (36.4%)<br>358 (8.3%) | <br>8 (0.4%)<br>1123 (58.2%)<br>646 (33.5%)<br>152 (7.9%) | <br>26 (1.0%)<br>1232 (51.6%)<br>925 (38.7%)<br>206 (8.6%) |
| Working hours per week, mean (SD) | 65.96 + 10.98 | 65.67 + 10.4 | 66.19 + 11.4 |
| Working hours per day, mean (SD) | 9.4 + 2.2 | 9.3 + 2.1 | 9.4 + 2.3 |
| Does your work involve night shift activity? | Yes 77.88<br>No 22.12 | Yes 78.28<br>No 21.72 | Yes 77.48<br>No 22.52 |
| Does your work involve vigorous-intensity activity? | Yes 51.3<br>No 48.7 | Yes 49.7<br>No 50.3 | Yes 52.9<br>No 47.1 |
| Does your work involve moderate-intensity activity? | Yes 59.1<br>No 40.9 | Yes 54.4<br>No 45.6 | Yes 63.8<br>No 36.2 |

Table 16. Seafarer

### 3.1.4 Discussion

The observed average weekly working hours of approximately 65-66 hours among maritime personnel reveal a demanding occupational landscape characterized by extended work durations. This trend is consistent with established research indicating a correlation between longer work periods and heightened risks of accidents and neuropsychological deficits (Rosa, 1995). Experimental studies underscore the deleterious effects of chronic sleep deprivation on cognitive function, particularly during circadian "night" periods (Harma, 1999). Shift work-induced fatigue has far-reaching health implications beyond cognitive impairments. Studies suggest that prolonged exposure to night and shift work disrupts gastrointestinal and cardiovascular functions through hormonal and sleepiness cycles (Knutsson, 2003). Moreover, shift workers tend to consume more pro-inflammatory diets, heightening their risk of cardiovascular diseases (Wirth, 2014). These risks are compounded by psychosocial factors such as poor work-life balance and physiological mechanisms like altered lipid and glucose metabolism (Puttonen, 2010). Incomplete recovery from work, especially in terms of inadequate rest periods, has been linked to an increased risk of cardiovascular disease mortality (Kivimaki, 2006). This finding is particularly pertinent for seafarers subjected to prolonged periods at sea, where access to adequate recovery time may be limited.

Furthermore, short sleep duration resulting from shift work has been associated with obesity and metabolic syndrome, driven by increased caloric intake and reduced energy expenditure (Pauksztat, 2017). The link between shift work and chronic diseases like coronary heart disease and type 2 diabetes is well-documented, with night shift work, in particular, posing heightened risks, especially for older workers (Hemio, 2014; Kubo, 2011). Additionally, shift work has been implicated in unfavorable dietary habits, increased calorie intake, and shorter sleep duration, further exacerbating metabolic dysregulation (Ramin, 2015). Recent meta-analyses have underscored the increased risk of diabetes mellitus associated with shift work, particularly among individuals with rotating shifts (Gan, 2015). Fatigue, a common consequence of irregular work hours such as shift work, often precipitates sleeping disorders like insomnia and sleep apnea/hypopnea, particularly among overweight individuals (Harma, 1999). Insomnia, characterized by difficulty falling or staying asleep, is prevalent among shift workers and contributes to fatigue-related impairments in behavior and social functioning. Sleep apnea, on the other hand, manifests as sleepiness and fatigue during waking hours, further exacerbating performance deficits. In conclusion, the findings underscore the multifaceted impact of extended work durations and shift work on the health and well-being of maritime personnel. Addressing these challenges requires comprehensive strategies encompassing improved work-hour regulations, enhanced sleep hygiene practices, and targeted interventions to mitigate the adverse health effects associated with prolonged occupational demands.

## 3.2 Comprehensive study on analysis of work performance in seafarer

### 3.2.1 Introduction

Historically, seafaring is known to be high-risk occupation with a high rate of lifestyle-related diseases, in which workers are usually exposed both to high fatigue levels and stress (Carotenuto, 2012; Allen, 2008). Previous research indicates that fatigue is of major importance in some sectors of the maritime industry, Grech found in a sample of 79 crew from 6 ships that more than 40% of participants worked more than 80 hours a week and more than 60% reported not getting a sufficient amount rest (Grech, 2003). Another study found that 61% of deck officers felt they were often affected by fatigue when on duty (Gander, 2005). Furthermore 26% of the ferry sample could recall to be involved in a fatigue related incident in the previous 6 months (Gander, 2005). Fatigue is a serious work place hazard and can be associated with safety and health of the worker. Symptoms of fatigue (loss of concentration, poor performance) can reduce a worker's ability to make decisions, ability to do complex planning whit serious consequences on health and wellbeing of seafarers

(International Maritime Organization, London 2001). Fatigue may impair almost all psycho-physical abilities including: speed, power, concentration, coordination, ability to make decisions. Published studies proposes an upper general tolerance limit over 8 hours working day, consisting of mixed physical work, of one third of a person's maximal aerobic capacity (Harrington, 2001; Jørgensen, 1985). Heavy physical work load is a potential risk factor for many different diseases, such as cardiovascular and musculoskeletal systems diseases (Virkkunen, 2007; Leino, 1988). Cardiovascular diseases (CVD) are an important concern in seafarers and accountable for high death rate and illness at sea. Studies found that more than 70% of the documented mortalities at sea were caused by cardiovascular diseases (Roberts, 2010). In a German survey, 465 nautical officers were interviewed about their experience about diseases and accidents on board, which had led to an emergency port call, a course deviation or an evacuation (Oldenburg, 2014). They referred that CVD were the second most frequent cause for serious medical emergencies on board (Oldenburg, 2014). An analysis of the trend of different groups of main pathologies assisted by Centro Internazionale Radio Medico (C.I.R.M.) along the years of activity of the Centre show that pathologies of the locomotor system represent a common problem on board ship (Mahdi, 2016). Time-motion analysis includes analyzing movement and the time spent on each movement through video analysis. This method is very powerful, since the investigator can analyze every second spent by each worker during every work shift. Time-motion analysis combined with physiologic data can be valuable in assessing the physiologic demand during work duty (Meade, 2016).

There are three discrete aims of this study. These are to:

1) Introduce time-motion analysis for assessing the impact of workplace load on duty activity in seafaring
2) Examine internal fatigue load: time spent by seafarer in low intensity activity during work (e.g. watching monitor in sitting position); time spent by seafarer in high intensity activity during work (e.g. move heavy loads); number of working hours.
3) Examine postural workload, it includes shoulder position, knee interspace, ankle position, and overall symmetry of the body during work duties.

### 3.2.2 Material and Method

The motions of seafarer were recorded by a video camera (Telemedicine station ECG-PNI), and videos were stored in memory cards (SanDisk ® Extreme PRO 64 GB). Videos were analyzed with software Kinovea™ on the laptop (Acer®, Notebook ES1-523). Kinovea™ is a free software application for analysis, it provides insertion of timers on screen, change the speed of display and switch frame by frame. 200 work-hours of 20 seafarer were recorded. Seafarer's mean age was 27.87±3.98 years, mean body mass index [BMI]: 25.26±3.21 kg/m2. Seafarer will group in 5 macro-categories: "Deck Officers" (include: Deck Cadet, Third Mate, Second Mate, Chief Mate, Master); "Deck Crew" (include: Boatswain, Able Seaman, Ordinary Seaman); "Engine Officers" (include: Chief Engineer, Second Engineer, Third Engineer, Fourth Engineer); "Engine Crew" (include: Motorman, Oiler, Wiper,); "Galley Staff" (include: Cook, Steward).


*Figure 9. Kinovea software*

*Figure 10. Telemedicine station ECG-PNI*

In order to asses internal fatigue load analysis of activities for the seafarer will carry out considering the following categories: *Low-intensity work activities (LIWA):* it includes working in a managerial or supervisory capacity, performing inventory; ordering supplies; organization of supplies or records; workplace inspections; answering the phones; working in sitting position; typing and filing reports; write; pinch; walk; remaining in a seated position; remaining in upright position; seizing, grasping, holding, turning, or otherwise working with the hands; *High-intensity work activities (HIWA):* moving an object from one level to another; transporting an object over a distance, usually holding in the hands, or on the arm(s) or shoulder(s); transporting an object over a distance, usually holding in the hands, or on the arm(s) or shoulder(s); exerting force upon an object in order to move the object away from worker; exerting force upon an object in order to move the object towards worker; kneel; crouch/squat. 4 dependent variables were included in the research: number of LIWA (LIWAn); total time of LIWA (LIWAt); number of HIWA (HIWAn); total time of HIWA (HIWAt). Dependent variables were compared between 4 independent variables regarding Rank class “Deck Rating”, “Deck Officer”, “Engine Rating”, “Engine Officer”, and Galley Staff.

Static postures for the back, arms and legs, were analyzed by a multidisciplinary approach, ranging from video recording, computer programs (I.E. Kinovea®), and evaluated by posture assessment system (IISO 11226 standard) (Table 17). 6 dependent variables were included in the research: Acceptable Trunk Inclination (ATI), Not Acceptable Trunk Inclination (NATI), Acceptable Knee Flexion (AKF), Not Acceptable Knee Flexion (NAKF), Acceptable Arm Elevation (AAE), Not Acceptable Arm Elevation (NAAE). Dependent variables were compared between 4 independent variables regarding Rank class “Deck Rating”, “Deck Officer”, “Engine Rating”, “Engine Officer”, and Galley Staff.

| Body position | Angle | Definition |
|---|---|---|
| Trunk inclination (α) | 0 °< α < 20° | Acceptable trunk inclination |
| | 20 °< α < 60° | Trunk forward inclination. The holding time is evaluated according t > -0.075 + 5.5α where t is time in minutes and α is angle in degrees. If inequality is true. Not recommended. |
| | α > 60° | Trunk backward inclination. Not recommended position |
| Knee flexion (β) | β > 140° | Acceptable knee flexion. |
| | 90 °< β < 140° | Extreme knee flexion. Not recommended position |
| Arm elevation (γ) | 0 °< γ < 20° | Acceptable upper arm elevation |
| | 20 °< γ < 60° | The holding time is evaluated according t> -0.05γ+4. If inequality is true. Not recommended. |
| | γ > 60° | Not recommended position |

***Table 17. IISO 11226 standard***

Statistical analysis was made with software Past. LIWAn, LIWAt, HIWAn, HIWAt, ATI, NATI, AKF, NAKF, AAE, NAAE are presented as the mean ± SD. Before using the analysis of variance, the assumptions of normality were verified. Statistical significance was set at $p < 0.05$. A one-way analysis of variance (ANOVA) was used to test the differences between the rank categories. When a significant F value was found, Bonferroni's post-hoc tests were applied. Effect size (ES) in the analysis of variance (ANOVA) was computed as $\omega^2$, to assess the meaningfulness of differences, with $\omega^2 < 0.01$, $0.01 < \omega^2 < 0.06$, $0.06 < \omega^2 < 0.14$, and $\omega^2 > 0.14$, as trivial, small, moderate, and large ES, respectively. Chi-square or Fisher's exact test was used to analyse distributional differences in rank

### 3.2.3 *Results*

Overall, seafarer spend 12.8% of work time in High intensity activity. HIWA was measured in terms of mean minutes per hour and total time, along with the mean number of activities per hour and total time of activities. The mean time spent in HIWA during the work-shift by Deck Officer was 4.33 ± 1.59 minutes per hour, with a total time of 192 minutes. In Deck Officer rank group, the mean number of activities per hour (HIWAn) was 9.4 ± 1.4, totaling 371 activities. Deck Crew exhibited a substantially higher mean HIWAt of 9.53 ± 2.59 minutes per hour, resulting in a total time of 388 minutes. The mean HIWAn was 13.9 ± 2.9, with a total of 530 activities. The mean HIWAt during work-shift by Engine Officer was 5.47 ± 1.48 minutes per hour, totaling 223 minutes. The mean HIWAn was 9.6 ± 1.2, with a total of 387 activities. Engine Crew displayed a mean HIWAt of 10.47 ± 3.51 minutes per hour, with a total time of 434 minutes. The mean HIWAn was 13 ± 2.6, totaling 566 activities. Galley Staff showcased a mean HIWAt of 7.90 ± 1.41 minutes per hour, resulting in a total time of 322 minutes. The mean HIWAn was 11.3 ± 1.2, with a total of 435 activities.

**LIWAt:** Deck Officer achieved a mean LIWAt of 54.19 ± 1.59 minutes per hour, accounting for 92.56% of total activity time. The mean LIWAn was 9.5 ± 1.6, with a total of 365 activities. Deck Crew presented a mean LIWAt of 49.13 ± 2.59 minutes per hour, representing 83.75% of total activity time. The mean LIWAn was 14.5 ± 2.8, totaling 584 activities. Engine Officer maintained a mean LIWAt of 53.15 ± 1.48 minutes per hour, accounting for 90.67% of total activity time. The mean LIWAn was 9.5 ± 1.3, with a total of 374 activities. Engine Crew demonstrated a mean LIWAt of 48.04 ± 3.51 minutes per hour, accounting for 82.11% of total activity time. The mean LIWAn was 13.9 ± 3.0, totaling 555 activities. Galley Staff presented a mean LIWAt of 50.72 ± 1.47 minutes per hour, representing 86.52% of total activity time. The mean LIWAn was 11.3 ± 1.2, with a total of 442 activities. The recorded Accettable Trunk inclination and not acceptable Trunk inclination per hours were respectively: 6.4 ± 1.4, 2.1 ± 0.6 on Deck Officer; 15.5 ± 6.0, 4.7 ± 2.5 on Deck Crew; 8.1 ± 2.3, 3.5 ± 1.4 on Engine Officer; 14.8 ± 6.4, 4.3 ± 1.8 on Engine Crew; 11.6 ± 4.5, 4.2 ± 2.0 on Galley Staff. Accettable knee flexion recorder per hours were 6.2 ± 1.5 for Deck Officer; 19.7 ± 2.5 for Deck Crew; 2.5 ± 0.9 for Engine Officer; 19.7 ± 3.2 for Engine Crew; 17.2 1.5 for Galley Staff; while not acceptable knee flexion per hours were 1.9 ± 0.6 on Deck Officer, 10.5 ± 3.5 on Deck Crew, 1.3 ± 0.3 on Engine Officer, 4.1 ± 2.0 on Engine Crew, and 3.9 ± 1.8 on Galley Staff. Lastly recorded Acceptable arm elevation and not acceptable arm elevation per hours were respectively: 6.4 ± 1.4, 1.9 ± 0.6 on Deck Officer; 14.7 ± 6.3, 5.8 ± 2.4 on Deck Crew; 8.0 ± 2.7, 3.2 ± 1.3 on Engine Officer; 14.4 ± 6.4, 3.8 ± 1.8 on Engine Crew; 10.8 ± 4.4, 4.3 ± 1.7 on Galley Staff (Table 19).

| Variables | | Deck Officer | Deck Crew | Engine Officer | Engine Crew | Galley Staff |
|---|---|---|---|---|---|---|
| | % | 7.4 | 16.2 | 9.3 | 17.8 | 13.4 |
| HIWAt | Mean and SD Minute per hours | 4.33 ± 1.59 | 9.53 ± 2.59 | 5.47 ± 1.48 | 10.47 ± 3.51 | 7.90 ± 1.41 |
| | Total time | 192 | 388 | 223 | 434 | 322 |
| HIWAn | Mean and SD number per hours | 9.4 ± 1.4 | 13.9 ± 2.9 | 9.6 ± 1.2 | 13 ± 2.6 | 11.3 ± 1.2 |
| | Total | 371 | 530 | 387 | 566 | 435 |
| LIWAt | % | 92.56 | 83.75 | 90.67 | 82.11 | 86.52 |
| | Mean and SD Minute per hours | 54.19 ± 1.59 | 49.13 ± 2.59 | 53.15 ± 1.48 | 48.04 ± 3.51 | 50.72 ± 1.47 |
| | Total time | 2208 | 2012 | 2177 | 1966 | 2078 |
| LIWAn | Mean and SD number per hours | 9.5 ± 1.6 | 14.5 ± 2.8 | 9.5 ± 1.3 | 13.9 ± 3.0 | 11.3 ± 1.2 |
| | Total | 365 | 584 | 374 | 555 | 442 |

Table 18. HIWA and LIWA among rank on board

| Variables | Deck Officer | | Deck Crew | | Engine Officer | | Engine Crew | | Galley Staff | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Trunk inclination (α)** | **A** | **N** | **A** | **N** | **A** | **N** | **A** | **N** | **A** | **N** |
| **Mean per hours** | 6.4 | 2.1 | 15.5 | 4.7 | 8.1 | 3.5 | 14.8 | 4.3 | 11.6 | 4.2 |
| **SD** | ± 1.4 | ± 0.6 | ± 6.0 | ± 2.5 | ± 2.3 | ± 1.4 | ± 6.4 | ± 1.8 | ± 4.5 | ± 2.0 |
| **Total posture** | 263 | 87 | 635 | 194 | 331 | 143 | 608 | 177 | 477 | 174 |
| | | | | | | | | | | |
| **Knee flexion (β)** | **A** | **N** | **A** | **N** | **A** | **N** | **A** | **N** | **A** | **N** |
| **Mean per hours** | 6.2 | 1.9 | 19.7 | 10.5 | 2.5 | 1.3 | 19.7 | 4.1 | 17.2 | 3.9 |
| **SD** | ± 1.5 | ± 0.6 | ± 2.5 | ± 3.5 | ± 0.9 | ± 0.3 | ± 3.2 | ± 2.0 | 1.5 | ± 1.8 |
| **Total posture** | 255 | 80 | 807 | 430 | 104 | 137 | 808 | 167 | 706 | 159 |
| | | | | | | | | | | |
| **Arm elevation (γ)** | **A** | **N** | **A** | **N** | **A** | **N** | **A** | **N** | **A** | **N** |
| **Mean per hours** | 6.4 | 1.9 | 14.7 | 5.8 | 8.0 | 3.2 | 14.4 | 3.8 | 10.8 | 4.3 |
| **SD** | ± 1.4 | ± 0.6 | ± 6.3 | ± 2.4 | ± 2.7 | ± 1.3 | ± 6.4 | ± 1.8 | ± 4.4 | ± 1.7 |
| **Total posture** | 261 | 79 | 603 | 237 | 329 | 133 | 589 | 154 | 442 | 175 |

Table 19. Accettable (**A**) and not accettable (**N**) posture among rank on board

When comparing HIWAt across rank groups, significant differences were observed ($F = 48.93$, $p < 0.05$, $\omega^2 0.4$). Specifically, Deck Crew and Engine Crew spent more time in HIWA than Engine Officer ($p < 0.005$), Galley Staff ($p < 0.005$), and Deck Officers ($p < 0.005$). Galley Staff spent more time in HIWA than Engine Officer ($p < 0.05$), and Deck Officers. Significant differences were also observed in LIWAt among rank groups ($F = 48.95$, $p < 0.005$, $\omega^2 0.4$). Engine Officer and Deck Officer spent more time in LIWA than Galley Staff ($p < 0.05$), Deck Crew ($p < 0.05$), and Engine Crew ($p < 0.05$). Significant main effects of Rank on board where found on HIWAn ($F = 55.78$, $p < 0.05$, $\omega^2 0.4$) Numbers of HIWA were found higher in Deck Crew comparing to Deck Officer ($p < 0.05$), Engine Officer ($p < 0.05$), and Galley Staff ($p < 0.05$). Numbers of HIWA were found higher in Engine Crew comparing to Deck Officer ($p < 0.05$), and Engine Officer ($p < 0.05$). Lastly, in Galley Staff HIWAn were higher than Deck Officer ($p < 0.05$), and Engine Officer ($p < 0.05$). When comparing LIWAn across rank groups, significant differences were observed ($F = 46.93$, $p < 0.05$, $\omega^2 0.5$). Deck Crew and Engine Crew show the higher number comparing to Deck Officer ($p < 0.05$), Engine Officer ($p < 0.05$), and Galley Staff ($p < 0.05$) (Table 20). Trunk inclination (α), knee flexion (β), and arm elevation (γ) were assessed for each rank group, comparing acceptable (A) and not acceptable (N) postures. For trunk inclination, no significant differences were observed among rank groups ($\chi 2 = 8.5$, $p = 0.9$). Similarly, no significant differences were found in knee flexion ($\chi 2 = 8.2$, $p = 0.4$) and arm elevation ($\chi 2 = 8.3$, $p = 0.9$) across rank groups. This suggests that posture categories were not influenced by the seafarer's rank (Table 21).

| HIWAt | **Deck Officer** | **Deck Crew** | **Engine Officer** | **Engine Crew** | **Galley Staff** | |
|---|---|---|---|---|---|---|
| **Deck Officer** | | **p: < 0.005** | p: > 0.5 | **p: < 0.005** | **p: < 0.005** | **F value** 48.93 |
| **Deck Crew** | **p: < 0.005** | | **p: < 0.005** | p: > 0.5 | **p: < 0.005** | |
| **Engine Officer** | p: > 0.5 | **p: < 0.005** | | **p: < 0.005** | **p: < 0.005** | |
| **Engine Crew** | **p: < 0.005** | p: > 0.5 | **p: < 0.005** | | **p: < 0.005** | $\omega^2$ 0.4 |
| **Galley Staff** | **p: < 0.005** | **p: < 0.005** | **p: < 0.005** | **p: < 0.005** | | |

| LIWAt | **Deck Officer** | **Deck Crew** | **Engine Officer** | **Engine Crew** | **Galley Staff** | |
|---|---|---|---|---|---|---|
| **Deck Officer** | | **p: < 0.005** | p: > 0.5 | **p: < 0.005** | **p: < 0.005** | **F value** 48.95 |
| **Deck Crew** | **p: < 0.005** | | **p: < 0.005** | p: > 0.5 | **p: < 0.005** | |
| **Engine Officer** | p: > 0.5 | **p: < 0.005** | | **p: < 0.005** | **p: < 0.005** | |
| **Engine Crew** | **p: < 0.005** | p: > 0.5 | **p: < 0.005** | | **p: < 0.005** | $\omega^2$ 0.4 |
| **Galley Staff** | **p: < 0.005** | **p: < 0.005** | **p: < 0.005** | **p: < 0.005** | | |

| HIWAn | **Deck Officer** | **Deck Crew** | **Engine Officer** | **Engine Crew** | **Galley Staff** | |
|---|---|---|---|---|---|---|
| **Deck Officer** | | **p: < 0.005** | p: > 0.5 | **p: < 0.005** | **p: < 0.005** | **F value** 55.78 |
| **Deck Crew** | **p: < 0.005** | | **p: < 0.005** | p: > 0.5 | **p: < 0.005** | |
| **Engine Officer** | p: > 0.5 | **p: < 0.005** | | **p: < 0.005** | p: > 0.5 | |
| **Engine Crew** | **p: < 0.005** | p: > 0.5 | **p: < 0.005** | | p: > 0.5 | $\omega^2$ 0.4 |
| **Galley Staff** | **p: < 0.005** | **p: < 0.005** | p: > 0.5 | p: > 0.5 | | |

| LIWAn | **Deck Officer** | **Deck Crew** | **Engine Officer** | **Engine Crew** | **Galley Staff** | |
|---|---|---|---|---|---|---|
| **Deck Officer** | | **p: < 0.005** | p: > 0.5 | **p: < 0.005** | **p: < 0.005** | **F value** 46.31 |
| **Deck Crew** | **p: < 0.005** | | **p: < 0.005** | p: > 0.5 | **p: < 0.005** | |
| **Engine Officer** | p: > 0.5 | **p: < 0.005** | | **p: < 0.005** | p: > 0.5 | |
| **Engine Crew** | **p: < 0.005** | p: > 0.5 | **p: < 0.005** | | **p: < 0.005** | $\omega^2$ 0.5 |
| **Galley Staff** | **p: < 0.005** | **p: < 0.005** | p: > 0.5 | **p: < 0.005** | | |

Table 20. Anova test and Bonferroni correction on HIWAt, LIWAt, HIWAn, LIWAn among rank on board

| Trunk inclination (α) | Accettable | | Not Accettable | | Total | Chi$^2$ |
|---|---|---|---|---|---|---|
| | No | % | No | % | No | |
| **Deck Officer** | 6.4 | 75.1 | 2.1 | 24.9 | 8.5 | **F: 0.2 p: 0.9** |
| **Deck Crew** | 15.5 | 76.6 | 4.7 | 23.4 | 20.2 | |
| **Engine Officer** | 8.1 | 69.9 | 3.5 | 30.1 | 11.6 | |
| **Engine Crew** | 14.8 | 77.5 | 4.3 | 22.5 | 19.1 | |
| **Galley Staff** | 11.6 | 73.3 | 4.2 | 26.7 | 15.9 | |

| Knee flexion (β) | Accettable | | Not Accettable | | Total | Chi$^2$ |
|---|---|---|---|---|---|---|
| | No | % | No | % | No | |
| **Deck Officer** | 6.2 | 76.2 | 1.9 | 23.8 | 8.2 | **F: 3.7 p: 0.4** |
| **Deck Crew** | 19.7 | 65.3 | 10.5 | 34.7 | 30.2 | |
| **Engine Officer** | 2.5 | 66.2 | 1.3 | 33.8 | 3.8 | |
| **Engine Crew** | 19.7 | 82.9 | 4.1 | 17.1 | 23.8 | |
| **Galley Staff** | 17.2 | 81.6 | 3.9 | 18.4 | 21.1 | |

| Arm elevation (γ) | Accettable | | Not Accettable | | Total | Chi$^2$ |
|---|---|---|---|---|---|---|
| | No | % | No | % | No | |
| **Deck Officer** | 6.4 | 23.2 | 1.9 | 23.2 | 8.3 | **F: 1 p: 0.9** |
| **Deck Crew** | 14.7 | 28.2 | 5.8 | 28.2 | 20.5 | |
| **Engine Officer** | 8.0 | 28.8 | 3.2 | 28.8 | 11.3 | |
| **Engine Crew** | 14.4 | 20.7 | 3.8 | 20.7 | 18.1 | |
| **Galley Staff** | 10,8 | 28,3 | 4,3 | 28,3 | 15,0 | |

Table 21. Accettable (**A**) and not accettable (**N**) posture comparation among rank on board

### 3.2.4 **Discussion**

The findings from the analysis of time spent in High-Intensity Work Activity (HIWA) and Low-Intensity Work Activity (LIWA) among different ranks on board reveal several notable trends and patterns. Firstly, the mean time spent in HIWA and LIWA varied significantly across officer ranks and crew positions, indicating differences in work intensity and activity levels among them. Deck Crew and Engine Crew demonstrated higher mean times compared to Deck Officers and Engine Officers. The statistical analysis using ANOVA tests and Bonferroni correction provided insights into the significance of these differences among ranks. Significant differences were observed in HIWA, LIWA, HIWAn, and LIWAn across ranks, highlighting the importance of considering rank or position when assessing work intensity and activity levels on board. Effort to pause ratio durign work were 0.21:1, Engine Crew, 0.19:1 for Deck Crew, 0.15:1 for Galley Staff, and 0.1:1 for Officers. In our study, we discovered that high-intensity work activity accounts for only 10% of seafarer performance, highlighting the necessity of considering other factors when assessing seafarer stressors. Physical stressors, including heat in workplaces, noise, ship movement, seasickness, strenuous physical labor, lifting, carrying, lack of exercise, and climatic changes during voyages, emerge as critical factors influencing seafarers' stress levels while on board (Rengamani, 2012). Psychosocial stressors, such as irregular shifts, long working hours per day, irregular working schedules, and sleep deprivation, significantly contribute to seafarers' stress, potentially leading to accidents. Social stressors stemming from migration, such as separation from family, extended periods on board, conflicts among crew members, and feelings of isolation, further exacerbate seafarers' detachment from social life. The demanding nature of work, characterized by time pressure, intense activities, a high workload, significant responsibility for one's actions, decision-making pressure, monotony, and lack of autonomy, emerges as a paramount stress factor. Additionally, the managerial burden, encompassing insufficient qualifications of subordinate crew members and significant responsibility for the work of others, can adversely impact seafarers' morale (Rengamani, 2012). Job demands extend beyond traditional notions of workload and circadian disturbance. Pauksztat (2017) reveals that job demands in the maritime industry encompass various aspects such as the difficulty of the work, the ability to plan ahead, and intrusions from third parties. Pauksztat (2017) identifies two interconnected processes through which job demands influence outcomes. Firstly, they have direct and indirect effects on fatigue and the working climate on board. Secondly, certain positive aspects of job demands, such as engaging work and satisfactory pay, are linked with increased motivation and reduced turnover rates. Furthermore, external constraints play a role: The study highlights how external constraints, such as regulatory frameworks or industry practices, can either alleviate or exacerbate the effects of job demands on seafarers' work and well-being. Considering this perspective, although our study lacks follow-up data, the disparities observed among rank groups suggest significant variations in job demands across different roles on board. This could be attributed to the repetitive nature of their tasks. Further research is warranted in this regard.

Regarding posture assessment, the analysis of trunk inclination (α), knee flexion (β), and arm elevation (γ) revealed varying degrees of acceptable and unacceptable postures among ranks. Differences in posture may be attributed to the nature of tasks performed and ergonomic factors associated with specific roles on board. Despite the numerical disparities observed across different departments, the analysis has revealed a similarity in the relationship between not acceptable postures among total postur. We found similarities between non-officers seafarer with another category of workers at risk of musculoskeletal issues, nurses (Freitag, 2007; Morlock, 2000)**.** Freitag (2007) reported a high number of trunk inclinations per hour in this category, specifically 33 every 60 minutes. Morlock et al. (2000) reported that nurses engage in hazardous trunk inclinations 13.6 times per hour. The findings presented herein offer novel insights that can be leveraged to develop targeted prevention strategies tailored to specific ranks. Nonetheless, the characterization of these traits serves as a valuable starting point for identifying key areas for health promotion. Furthermore, the effectiveness of the work environment stands out as a crucial factor. Alarmingly, half of the respondents acknowledged their workplace as poorly organized. In contrast, individuals at home can rest more and engage in physical activity, facilitating a broader range of bodily movements. To address these issues, focused exercise regimes, ergonomic enhancements in workplaces, and increased job diversity on board appear imperative measures. Exercise emphasizing form and function, ergonomic enhancements in the workplace, and greater job variety are strong

### 3.2.5 Conclusion

In conclusion, the comprehensive analysis of musculoskeletal health among maritime personnel highlights several crucial findings and underscores the multifaceted nature of risk factors contributing to their well-being. The evidence presented here illuminates the intricate interplay between occupational demands, working conditions, and health outcomes, particularly concerning musculoskeletal disorders and the impact of extended work durations and shift work. The study identifies a spectrum of risk factors predisposing maritime personnel to musculoskeletal diseases, ranging from whole-body vibrations and ergonomic strain to monotonous work and poor supervisor-employee relationships. Notably, low back pain emerges as a significant concern, with distinct variations in its duration among rank groups, indicating the differential impact of job loads across different types of work on board. Contrary to conventional wisdom, our findings reveal that the majority of low back pain issues occur among younger seafarers, possibly due to the repetitive nature of their tasks. This challenges prevailing notions associating musculoskeletal problems with advancing age, suggesting a need for targeted interventions addressing the specific needs of younger maritime personnel. Moreover, the study underscores the importance of the work environment in influencing musculoskeletal health outcomes, with half of the respondents reporting poorly organized workplaces. This highlights the critical role of ergonomic improvements and job variation in mitigating the risk of musculoskeletal disorders among maritime personnel. The discussion extends beyond musculoskeletal health to encompass broader occupational challenges, including extended work durations and the adverse effects of shift work on various physiological and psychological parameters. Shift work-induced fatigue, inadequate recovery periods, and disrupted sleep patterns emerge as key concerns, with implications for cardiovascular health, metabolic dysregulation, and overall well-being. Importantly, the study draws parallels between non-officer seafarers and other high-risk occupational groups, such as nurses, shedding light on shared challenges and potential avenues for intervention. Additionally, the identification of unhealthy lifestyle trends among maritime personnel underscores the need for holistic approaches addressing not only occupational factors but also individual behaviors and habits. In light of these findings, the development of targeted prevention strategies tailored to specific rank-related factors is imperative. This necessitates collaborative efforts involving maritime industry stakeholders, health professionals, and policymakers to implement evidence-based interventions aimed at improving musculoskeletal health and overall well-being among maritime personnel. In conclusion, while this study provides valuable insights into the complex dynamics of musculoskeletal health among maritime personnel, further research is warranted to elucidate additional factors and refine intervention strategies. By prioritizing the well-being of maritime personnel and implementing proactive measures, we can strive towards a safer and healthier working environment for all.

### 3.3. Health risks associated with sedentary behavior

Prolonged sitting or lying down has been found to increase the risk of developing chronic conditions such as obesity, diabetes, and cardiovascular diseases. Furthermore, sedentary behavior has been associated with musculoskeletal disorders, including back pain and stiffness, as well as reduced muscle strength and flexibility (Chong, 2019). The lack of physical activity due to sedentary behavior also negatively affects mental health, increasing the risk of anxiety and depression. Seafarers need to be aware of the potential health risks associated with their sedentary lifestyle and take proactive measures to incorporate physical activity into their daily routines.

The lack of physical activity and increased sedentary behavior among seafarers may lead to an increased risk of cardiovascular diseases. Several studies have shown a significant association between sedentary lifestyles and the development of cardiovascular diseases (Carballo, 2020). This sedentary behavior can be attributed to the nature of seafarer's work, which often involves long hours of sitting and limited opportunities for exercise. Moreover, restricted access to healthy food options and exposure to high-stress environments can further exacerbate the risk of cardiovascular diseases among seafarers. In view of this, is important to emphasize the importance of physical activity and encourage seafarers to adopt a more active lifestyle to mitigate these risks.

Musculoskeletal problems and obesity are two significant health concerns among seafarers (Wong, 2018). The nature of their work, which often involves long hours of inactivity and sedentary behavior, contributes to a higher risk of both conditions. Prolonged sitting or standing, heavy lifting, and repetitive motions can lead to musculoskeletal disorders such as back pain, joint stiffness, and muscle strains. Moreover, seafarers are more prone to obesity due to limited access to healthy food options and the consumption of high-fat, high-calorie meals. These issues not only negatively affect the well-being and quality of life of seafarers but can also impact their job performance and safety at sea.

Another important aspect to consider when discussing the physical and mental well-being of seafarers is the prevalence of mental health issues such as depression and anxiety. The unique challenges and isolation associated with life at sea can be a significant trigger for these conditions. Seafarers often experience long periods of separation from their families and friends, lack of social support, and limited access to mental health resources. Moreover, the demanding nature of their jobs, coupled with the constant exposure to stressful situations, can further exacerbate mental health issues. As a result, it becomes essential to develop comprehensive programs that prioritize mental health support for seafarers, including counseling services and educational initiatives aimed at raising awareness and reducing the stigma associated with mental health. One effective strategy to reduce sedentary behavior among seafarers is to promote regular physical activity on board ships (Qin, 2021). Encouraging seafarers to engage in structured exercise programs, such as group workouts or fitness classes, can not only provide a means for individuals to stay active but also foster a supportive and social environment. Providing access to fitness equipment and facilities, as well as organizing outdoor recreational activities during shore leave, can further motivate seafarers to engage in physical activity and decrease sedentary behavior. By implementing these strategies, seafarers can maintain their health and well-being while at sea.

To address the issue of sedentary behavior among seafarers, one potential solution is to encourage regular breaks and movement during working hours. Prolonged sitting can have detrimental effects on both physical and mental health (Sargent, 2017). By promoting the importance of taking breaks and engaging in physical activity, employers can instill a culture of wellness and prioritize the well-being of their workforce. Implementing policies that allow for scheduled breaks and providing designated areas for physical activity on board ships can ensure that seafarers have the opportunity to incorporate movement into their daily routines. Educating seafarers about the benefits of regular breaks and physical activity can empower them to make healthier choices and prioritize their overall health and well-being.

An Italian project endeavored to transform routine waiting periods into opportunities for simple stretching and mobilization exercises (Pasquarella, 2022). The project, divided into pre-intervention, intervention, and post-intervention phases, elicited significant participation and high approval rates (97%). A notable increase in willingness to engage in exercises during daily waiting breaks (68% pre-intervention vs. 94% post-intervention) and heightened belief in the positive health outcomes of physical activity (74% pre-intervention vs. 96% post-intervention) was observed. This project represents a significant contribution to increasing awareness of the importance of physical activity and promoting a culture of movement across all age groups (Pasquarella, 2022). Elastic resistance bands offer versatility, affordability, and space efficiency, making them suitable for work-based training and active pauses (Bergquist, 2018). Studies have shown comparable muscle activation between resistance bands and traditional equipment, particularly for single-joint exercises. Additionally, resistance bands may provide a viable alternative for multi-joint exercises, further enhancing their utility in promoting physical activity (Iversen, 2017). Integrating resistance bands into active pauses presents a promising strategy to combat sedentary behavior and promote physical activity in various settings. By leveraging elastic resistance bands, individuals can maximize the benefits of active pauses, contributing to a culture of movement and improved health outcomes.

Promoting active leisure activities onboard is crucial for seafarers to maintain their physical fitness and overall well-being. As seafaring involves long periods of inactivity and sedentary behavior, encouraging active leisure activities can help to counter the negative effects of a sedentary lifestyle (Nas, 2014). Implementing onboard exercise programs, providing access to sports facilities, and organizing group activities such as hiking or team sports can all contribute to keeping seafarers physically active. By promoting active leisure onboard, seafarers can enhance their cardiovascular health, improve mental well-being, and reduce the risk of chronic diseases associated with sedentary behavior.

To address the issue of sedentary behavior among seafarers, it is essential to raise awareness about its negative effects (Brown, 2019). By educating seafarers about the detrimental consequences of prolonged sitting and physical inactivity, we can encourage them to adopt healthier habits. Sedentary behavior has been associated with an increased risk of various health problems, including obesity, heart disease, and musculoskeletal issues. By highlighting these potential dangers, we can motivate seafarers to incorporate regular physical activity into their daily routine and make conscious efforts to reduce sedentary behaviors, thus promoting a healthier lifestyle at sea.

### 3.4 Conclusions

The work has provided valuable insights into the prevalence, risk factors, and impacts of various health conditions among seafarers, with a particular focus on hypertension, musculoskeletal disorders (MSDs) such as Low Back Pain (LBP), and the effects of extended work durations and shift work on seafarers' health and well-being. Through the analysis of data from multiple sources, including the Centro Internazionale Radio Medico (C.I.R.M.) database and previous research studies, several key findings have emerged, shedding light on the complex interplay between occupational factors, lifestyle behaviors, and health outcomes among maritime personnel. The analysis of data from the Centro Internazionale Radio Medico (C.I.R.M.) database provides valuable insights into the prevalence, distribution, and risk factors of cardiovascular diseases (CVD) among seafarers. The findings of this study underscore the significant burden of CVD among maritime personnel and highlight the importance of addressing modifiable risk factors and implementing targeted interventions to improve the cardiovascular health and well-being of seafarers worldwide. The study reveals that CVD is a significant health concern among seafarers, accounting for a considerable proportion of medical contacts to C.I.R.M. over the study period. Hypertensive disease emerges as the most common CVD among seafarers, followed by ischemic heart disease (IHD). Arterial hypertension is identified as the primary cardiovascular diagnosis, reflecting findings from previous studies highlighting the high prevalence of hypertension among maritime personnel (Tu, 2016). Several factors contribute to the elevated risk of CVD among seafarers, including exposure to noise, job strain, fatigue, vessel-specific stressors, unhealthy lifestyle behaviors, and limited access to comprehensive medical care and diagnostic resources on board ships. The findings suggest that non-officers may be particularly vulnerable to CVD due to differences in stress management, lifestyle risk factors, and high work-related stressors compared to officers (Oldenburg, 2010). Despite advancements in medical technology and telemedicine, the diagnosis and management of CVD remain challenging in the maritime industry due to limited access to diagnostic devices and trained medical professionals on board ships. The lack of comprehensive pre-employment medical screenings and diagnostic resources poses significant challenges in accurately assessing and managing CVD among seafarers. The findings of this study underscore the importance of implementing targeted interventions aimed at reducing the burden of CVD among seafarers. Hypertension is one of the most important and sensitive individuals are more susceptible than others to modified cardiovascular risk factor (Mac Mahon, 1990). In industrialized countries it is a cause of stroke, congestive heart failure and peripheral vascular disease because of its high prevalence (Fiebach, 1989). It accelerates atherogenesis, imparting a 2- to 3-fold increased risk of such events (Leishman, 1963) The findings presented in this study shed light on several important risk factors associated with hypertension among seafarers, emphasizing the need for targeted interventions and telemedicine strategies to mitigate the impact of modifiable risk factors on cardiovascular health. Through a comprehensive analysis of various risk factors, including working hours, work experience, worksite, alcohol consumption, and snoring, this study provides valuable insights into the epidemiology of HTN among seafarers and underscores the importance of proactive measures to prevent and manage this chronic health condition. Epidemiological research has suggested that the work environment, especially work stress, plays an important role in the development of hypertension (Greiner, 2004). Research suggests that long work hours may also be a work environment risk factor for hypertension (Steptoe, 2004). The extensive working hours endured by maritime personnel paint a picture of a demanding occupational landscape, characterized by prolonged work durations that have far-reaching implications for health and well-being. This phenomenon aligns with established research linking longer work periods to increased risks of accidents and neuropsychological deficits. Fatigue, a common consequence of irregular work hours such as shift work, often leads to sleeping disorders like insomnia and sleep apnea/hypopnea, particularly among overweight individuals. Insomnia and sleep apnea exacerbate performance deficits, impacting behavior and social functioning.  Consistent with previous research conducted in the general population (Landsbergis, 2003), our study confirms a positive association between long working hours and the prevalence of hypertension among seafarers. The findings suggest that seafarers working longer hours per week are at a significantly higher risk of reporting hypertension compared to those working fewer hours. This highlights the importance of implementing telemedicine strategies targeting long working hours to reduce the risk of hypertension among seafarers, thereby promoting cardiovascular health in this population.

Three potentially harmful workplace factors that are common across maritime work settings were included in the National Health Interview Survey-Occupational Health Supplement (NHIS-OHS): job insecurity, work family imbalance, and hostile work environments. Job insecurity can be defined as "the employee's perception of potential threat to continuity in one's current employment" (Lee, 2004). Among men in the general population, the fear or threat of unemployment has been shown to increase the likelihood of developing hypertension independent of demographic and behavioral risk factors (Levenstein, 2001). Work-family imbalance, or work-family conflict, is defined as "a type of inter-role conflict that occurs as a result of incompatible role pressures from the work and family domains" (Greenhaus et al., 2006). Work family imbalance has been longitudinally linked to depression, poor physical health, and hypertension (Wang, 2006). Our study also identifies work experience as an independent risk factor for hypertension among seafarers, with those having 10 years or more of experience at sea being at a significantly higher risk of reporting hypertension compared to their less experienced counterparts. This underscores the need for proactive measures to address job stress and promote healthy work environments to prevent the development of hypertension and other related health conditions among seafarers with longer work experience. Furthermore, our findings reveal a significant association between worksite on board ships and the prevalence of hypertension among seafarers. Specifically, individuals working in the deck room are found to have a higher likelihood of reporting hypertension compared to those working in the galley room or catering. This underscores the importance of addressing work-related stress and promoting healthy work environments, particularly in high-stress jobs such as those in the deck room, to prevent the development of hypertension among seafarers. Considerable evidence supports an association between excessive alcohol intake and an increased risk of hypertension (Tsuruta M, 2000). This association persists regardless of beverage type (Klatsky, 2004) Our study highlights alcohol consumption as an independent risk factor for hypertension among seafarers, with those consuming alcohol being significantly more likely to report hypertension compared to non-drinkers. This underscores the importance of implementing stricter limits on alcohol consumption based on international conventions and promoting healthy lifestyles to reduce the risk of hypertension among seafarers. A number of surveys have addressed the issue of whether there is an association between snoring and hypertension. In many studies a significantly higher prevalence of hypertension has been found among habitual snorers than among nonsnoring individuals (Koskenvuo, 1985; Guilleminault, 1983,). Our findings suggest that snoring is a significant risk factor for hypertension among seafarers, with snorers being at a significantly higher risk of reporting hypertension compared to non-snorers. This underscores the importance of early detection and prevention of obstructive sleep apnea (OSA) syndrome, which is closely associated with hypertension. Telemedicine interventions targeting snoring and related sleep disorders can play a crucial role in reducing the risk of hypertension among seafarers. Hypertension and obesity are both very important issues in primary care in the 21st century and have become two growing worldwide epidemics (Flegal, 2002; Mokdad, 2001). Many epidemiological studies have shown a progressive increase in the prevalence of elevated blood pressure or hypertension with increasing obesity (Lamon-Fava, 1996; Wilson, 2002). Our findings also reveal a high prevalence of overweight and obesity among seafarers, with nearly 40% of participants being overweight and 9% being obese. This prevalence is consistent with previous studies in the maritime industry but lower than reported in some studies among Danish seafarers. The rank-specific prevalence of overweight and obesity was significantly higher among non-officers, potentially due to work-related stress and poor psychological well-being. Our study provides valuable insights into the relationship between body mass index (BMI) and blood pressure (BP), specifically systolic blood pressure (SBP) and diastolic blood pressure (DBP), among seafarers. The findings underscore the significant impact of BMI on BP levels and highlight the importance of proactive measures to address modifiable risk factors associated with hypertension in this population. Our analysis reveals a positive and significant correlation between BMI and both SBP and DBP among seafarers. While the relationship between BMI and DBP was observed to be slightly stronger than that with SBP, the overall findings suggest that increasing BMI levels are associated with higher BP levels. This underscores the importance of weight management programs and interventions to prevent and control hypertension among seafarers.

Thesis sheds light on the prevalence and characteristics of Low Back Pain (LBP) disorders among seafarers, highlighting the need for targeted prevention and intervention strategies to address this common health issue aboard ships. The findings underscore the significant impact of work-related factors and the importance of promoting a healthier work environment to mitigate the risk of LBP among seafarers. Our analysis of data from the Centro Internazionale Radio Medico (C.I.R.M) database reveals that LBP disorders are prevalent among seafarers, accounting for a substantial proportion of musculoskeletal disorders treated by C.I.R.M over the last four years. Approximately 45% of all musculoskeletal disorders treated during the period 2015-2021 were related to LBP, indicating the significant burden of this condition among seafarers. Several risk factors contribute to the development of LBP among seafarers, including obesity, overweight, lack of physical activity, whole-body vibrations, ergonomic strain, monotonous work, and poor supervisor-employee relationships. These factors, combined with the repetitive nature of certain tasks and poor ergonomics, can increase the risk of LBP and lead to prolonged absences from work, particularly among Deck Rating seafarers who experienced the longest duration of LBP-related absences. Interestingly, our findings suggest that LBP issues are most prevalent among seafarers aged between 25 and 45, contrary to some studies indicating an increase in LBP with age. This discrepancy may be attributed to the types of tasks performed by younger seafarers, which often involve more repetitive movements and physical strain compared to older seafarers engaged in supervisory roles. Despite the limitations of our study, including the lack of information on the population at risk and the inability to estimate prevalence and incidence rates, the findings provide valuable insights into the characteristics and distribution of LBP among seafarers. It is evident that promoting a healthier work environment, including ergonomic improvements, varied job tasks, and focused exercise programs, is essential for preventing and managing LBP among seafarers.

Over the last few decades, many studies have been done on workload. Workload is a key issue in investigating and developing the human-machine interactions which lead to comfort, efficiency, and safety in workplace (Zakerian, 2013). These are the aims of ergonomics (Rubio, 2004). Workload is not just specific to any job/duty, it is specific to each individual. This discussion includes individual capacity and motivation for work. In other words, it includes physical and psychological factors (Omolayo, 2013). Work pressure and excessive workload can jeopardize the health (Moriguchi, 2010). One group of injuries are musculoskeletal disorders which are considered the main health problems associated with the industrial workers (Nur, 2014). In fact, the imbalance between job requirements and individual abilities can lead to musculoskeletal disorders (Mazloumi, 2014). Among these disorders, low back pain is the most common and most costly problem that has entangled the workers of industrial countries (Collins, 2008). Many factors can affect the risk of low back pain (Björck-van Dijken, 2008), and work-related low back pain has become a very important concern in recent years (Ahmadi, 2014). According to reports, 22% of the 1.2 million occupational injuries and accidents in the United States leading to loss of working time are related to the low back pain (Collins, 2008).

Analysis of time spent in High-Intensity Work Activity (HIWA) and Low-Intensity Work Activity (LIWA) among different ranks on board reveals significant variations in work intensity and activity levels. Deck Crew and Engine Crew demonstrate higher mean times compared to Deck Officers and Engine Officers, indicating differences in the nature of tasks performed among ranks. There was a significant difference in the duration of diseases among rank groups. A low back injury forced Deck Rating seafarers to miss work on average for nine days, more than any other group of seafarers. The linking between differences in task intensity and the duration of diseases among crew members in the maritime industry can be understood through various factors that involve higher intensity tasks, such as heavy lifting, prolonged standing, or repetitive motions, can put greater physical strain on the body. This increased strain may lead to a higher risk of musculoskeletal injuries or conditions like low back pain, which could result in longer durations of illness or recovery. The demanding nature of work emerges as a paramount stress factor for seafarers, characterized by time pressure, intense activities, high workload, significant responsibility, decision-making pressure, monotony, and lack of autonomy. Additionally, the managerial burden, including insufficient qualifications of subordinate crew members and significant responsibility for the work of others, can adversely impact seafarers' morale. Analysis of trunk inclination, knee flexion, and arm elevation reveals varying degrees of acceptable and unacceptable postures among ranks, likely attributed to the nature of tasks performed and ergonomic factors associated with specific roles on board. Similarities between non-officers' postures and those of other workers at risk of musculoskeletal issues, such as nurses, highlight the importance of addressing ergonomic concerns among seafarers. Alarmingly, half of the respondents perceive their workplace as poorly organized. In contrast, individuals at home have more opportunities for rest and physical activity. Focused exercise regimes, ergonomic enhancements, and increased job variety on board are imperative measures to address these issues and improve seafarers' health and well-being.

## Future implications

The implications of this study extend beyond the realm of research, offering actionable insights that can inform policy, practice, and education within the maritime industry. Several key implications emerge from the findings:

Policy Development: The study underscores the need for robust policy frameworks aimed at promoting musculoskeletal health and well-being among maritime personnel. This includes implementing regulations to limit extended work durations, improve workplace ergonomics, and address the adverse effects of shift work on health outcomes.

Workplace Interventions: Employers within the maritime industry must prioritize interventions aimed at enhancing the work environment and mitigating risk factors associated with musculoskeletal disorders. This may involve investing in ergonomic improvements, providing training on safe work practices, and fostering supportive supervisor-employee relationships.

Health Promotion Initiatives: Proactive health promotion initiatives targeting maritime personnel can play a pivotal role in raising awareness about musculoskeletal health issues and encouraging healthy behaviors. This may include educational campaigns, wellness programs, and access to resources for physical activity and stress management.

Training and Education: Integrating musculoskeletal health education into training programs for maritime personnel is essential for equipping them with the knowledge and skills to prevent and manage work-related injuries. This includes instruction on proper lifting techniques, ergonomic principles, and strategies for maintaining musculoskeletal health during extended periods at sea.

Research and Collaboration: Continued research and collaboration are needed to further explore the complex interplay between occupational factors, individual behaviors, and health outcomes among maritime personnel. Multidisciplinary approaches involving researchers, practitioners, industry stakeholders, and policymakers can facilitate the development of evidence-based interventions and best practices.

Global Perspectives: Given the global nature of the maritime industry, efforts to address musculoskeletal health issues must extend beyond national boundaries. International collaboration and information-sharing mechanisms can facilitate the exchange of knowledge, resources, and best practices to improve musculoskeletal health outcomes for maritime personnel worldwide.

By embracing these implications and taking proactive steps to address musculoskeletal health within the maritime industry, stakeholders can foster a culture of safety, well-being, and resilience among maritime personnel. Ultimately, prioritizing musculoskeletal health is not only essential for protecting the workforce but also for sustaining the long-term viability and success of the maritime industry as a whole.

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