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LETTER TO THE EDITOR

Applications of metaverse for improving healthcare at sea

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The provision of adequate healthcare on board ships has always represented a challenge for medicine. In general, ships are at sea for days or weeks before they can reach a port and with the only exception of some large passenger or cruise ships, they do not carry health professionals on board. The maritime healthcare sector has expanded more quickly as a result of the quickening pace of digitalisation and automation, which has led to the creation of new models and new opportunities for seafarers' treatment provision at reduced costs. By enabling both onboard patients and medical personnel to have lifelike experiences, a new digital technology known as the metaverse has relevant potential for the healthcare of seafarers.

Not only how people use technology, but also how they relate to one another and the outside world, could all be altered by the metaverse. Some people think of the metaverse as more of a merging of the physical and digital worlds, where the real world is surrounded by digital surfaces and objects. These technologies working together ensure individualised, close-knit patient care. It also provides smart adaptive solutions that lower barriers between healthcare providers and patients [1].

Around the world, major corporations including Accenture, Vantage Health, Oura Ring, Mendelian, and others have started to investigate how this period would affect the healthcare system, particularly in light of the recent pandemics that has affected much of the seafarers across world. Several new use cases [2] make it evident how healthcare could change in the future various applications includes:

- Wellness for onboard patients and healthcare professionals is possible in the metaverse, just as it is for physicians. Doctors can explain and even demonstrate illness symptoms and treatment options using immersive environments. These settings can aid in teaching caregivers how to take care of a person in a shipping environment. Better health literacy and greater adherence to treatment plans can result in better outcomes when education is improved;
- Extended reality technologies are being used in new virtual therapies to assist patients with pain management, neurological problems, mental health, and physical wellness. Utilising an evidence-based infrastructure, the healthcare forum immerses patients in virtual settings and equips them with resources and coping mechanisms that will help them deal with stress, anxiety, and terror throughout their lives;
- Interoperability and tokenisation in context to Blockchain, Web3, autonomous driving, and artificial intelligence (AI) technologies have made it possible for users to safely own, share, and manage patient, provider, and payer data such as secure NFTs, payment rewards, the health identity and most importantly the management of complex records;
- The possible option of digital diagnosis via augmented reality is there which combines space, movement, and interactions to detect diseases. For example, by observing eye movements, medical professionals can notice neurological indicators or ocular disorders like glaucoma. These use cases show how healthcare organizations are beginning to push the boundaries of metaverse technology to provide state-of-the-art operational, clinical, and recreational experiences while transitioning from a centralized to a decentralised ecosystem.

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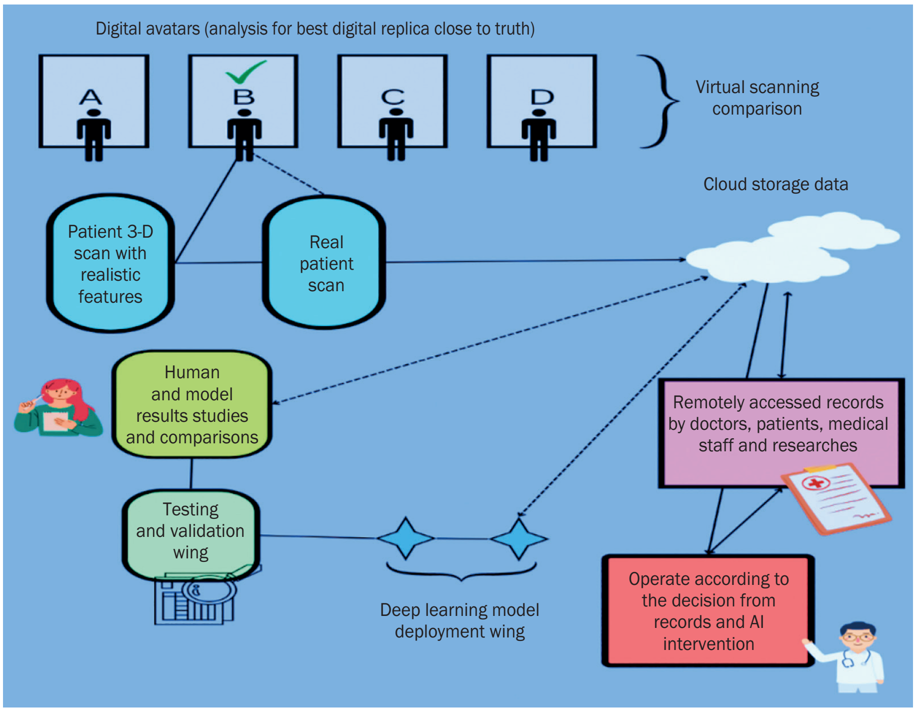

Figure 1. The working framework of intervention of metaverse in healthcare

There are many possible ways to conceptualise the workings of the metaverse in healthcare, but each model's fundamental building blocks share a common set of avatars, subsets, and connections [3]. In this, you can find the efforts that we did to illustrate how the metaverse functions when it is used as a platform for seafarers' healthcare. The identification of the eye glaucoma metaverse model has been proposed (Fig. 1). In the first phase, various avatars have been analysed to choose the one that is most realistic for a patient which is known as virtual scanning comparison [4]. The avatars, which are physical representations of individuals, replace actual patients. This information is continuously being stored in the clouds for further study. After the data is gathered, deep learning models are created and continually improved in the model deployment wing until they achieve high accuracy and minimal error. The following stage involves testing and validating the completed models. If the validation is weak, it will be sent back to the deployment wing for more model fine-tuning; if not, it will move on to the next stage for comparison for outcome analysis.

Further, this final result about the onboard patient will also be stored again on the cloud. Doctors, medical support personnel, patients, and other researchers with the proper authorisation can access the patient records that are kept on the cloud. The patient will be told about his condition and the best course of action after these records have been examined. If surgery is necessary, the patient will be instructed to arrive on the specified date. If the procedure can be avoided based on the results thus far, the patient will just be advised to take some medication. The physical meeting between the doctor and patient is minimised in both situations. The study's findings could be expanded upon and addressed to prospective uses of the technique in the marine industry forums, such as medical marketing, telemedicine, medical education and training of seafarers, healthcare facilities, and fitness and wellbeing.

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BMJ Open

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

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ABSTRACT

Objectives High blood pressure is a common health concern among seafarers. However, due to the remote nature of their work, it can be difficult for them to access regular monitoring of their blood pressure. Therefore, the development of a risk prediction model for hypertension in seafarers is important for early detection and prevention. This study developed a risk prediction model of self-reported hypertension for telemedicine.

Design A cross-sectional epidemiological study was employed.

Setting This study was conducted among seafarers aboard ships. Data on sociodemographic, occupational and health-related characteristics were collected using anonymous, standardised questionnaires.

Participants 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.

Outcome measures We calculated the adjusted OR (AOR) with 95% CIs using multiple logistic regression models to estimate the associations between sociodemographic, occupational and health-related characteristics and self-reported hypertension. We also developed a risk prediction model for self-reported hypertension for telemedicine based on seafarers' characteristics.

Results Among the 4318 participants, 55.3% and 44.7% were non-officers and officers, respectively. 20.8% (900) of the participants reported having hypertension. Multivariable analysis showed that age (AOR: 1.08, 95% CI 1.07 to 1.10), working long hours per week (AOR: 1.02, 95% CI 1.01 to 1.03), work experience at sea (10+ years) (AOR: 1.79, 95% CI 1.33 to 2.42), being a non-officer (AOR: 1.75, 95% CI 1.44 to 2.13), snoring (AOR: 3.58, 95% CI 2.96 to 4.34) and other health-related variables were independent predictors of self-reported hypertension, which were included in the final risk prediction model. The sensitivity, specificity and accuracy of the predictive model were 56.4%, 94.4% and 86.5%, respectively.

Conclusion A risk prediction model developed in the present study is accurate in predicting self-reported hypertension in seafarers' onboard ships.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This is the first study that has developed a risk prediction model based on seafarers' characteristics to predict the risk of self-reported hypertension for telemedicine interventions.
- ⇒ The risk prediction model is constructed based on easily obtainable characteristics of seafarers, which can be collected using telemedicine modalities, thereby allowing for its use during teleconsultations.
- ⇒ This study developed a risk prediction model using sociodemographic, occupational and health-related variables that showed high predictive power in distinguishing subjects with and without self-reported hypertension. This model could, therefore, be used during a telemedicine intervention at sea as a means of identifying individuals at high risk and supporting clinical decision-making.
- ⇒ We assessed self-reported hypertension and excluded participants who did not receive treatment despite having high blood pressure. Consequently, this selection criterion may cause an underestimation of the magnitude of hypertension among seafarers.

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.[1] CVDs are one of the leading causes of work-related mortality from disease in the maritime industry,[2 3] and their burden is attributable to mainly modifiable risk factors.[4] 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.[5–8]

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.[9 10] 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.[11] 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.[12–15] 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 kilometres 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.[10] 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.[16] 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.

MATERIALS AND METHODS

Study design and setting

A cross-sectional epidemiological study was conducted on board ships to determine the prevalence of HTN 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.

Participants and procedures

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.[17] 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.

Data collection

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,[18] the body weight and height of the participants were measured. The BMI was computed as follows: weight in kilograms (kg) divided by height in metres (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.

Table 1 Independent variables and their descriptions

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.

Statistical analysis

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 χ^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 1 shows a description of the independent variables.

Risk model building

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.

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:

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

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

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

where α is the value of intercept, β_i are regression coefficients, X_i are the sets of predictors.

Assessment of model fit

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.[19]

The Hosmer-Lemeshow goodness-of-fit statistic was used to measure calibration.[20] The Hosmer-Lemshow test is commonly used to evaluate a model's overall goodness of fit. The test is based on χ^2 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-R^2 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).[21 22] Pseudo-R^2 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-R^2 statistic is used to measure predictive strength in logistic regression. McFadden's pseudo R^2 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.[23] 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,[25] and R-package '*summarytools*' was used for frequencies tables, cross-tabulation and other descriptive statistics.[26] R-package '*glm2*' was used for running the univariable and multivariable analysis.[27] Its function 'glm' was used to fit the described model for different tested sets of independent variables and categorisations of those variables. In this study, statistical significance was determined by a p value of less than 0.05.

Patient and public involvement

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 International Maritime Organization and other stakeholders.

RESULTS

Sociodemographic, occupation and health-related characteristics

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 1. 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 2).

Univariable and multivariable analysis

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 3). These variables were also included in the multivariable 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 3).

A risk prediction model

Based on the multivariable analysis, the independent predictors presented in figure 1 were considered in the final risk prediction model for HTN (figure 1).

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)−0.20x Engine (E)−0.66x 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 (online supplemental table 1). In the online supplemental table 1, 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 goodness of fit statistics for the multivariable model is appropriate (X^2=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-R^2 estimates (the Cox and Snell pseudo-R^2=0.304, Nagelkerke pseudo-R^2=0.473 and McFadden pseudo-R^2=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 2).

DISCUSSION

The present study developed a risk prediction model to predict the risk of HTN for telemedicine intervention

Table 2 Sociodemographic, occupational and health-related characteristics among seafarers with and without self-reported hypertension

Variable	Overall (n=4318 (100%))*	Self-reported hypertension		P value†
		No (n=3418 (79.2%))*	Yes (n=900 (20.8%))*	
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.

based on the results of a large cross-sectional epidemiological study and taking into account the sociodemographic, 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 telemedicine. 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

Table 3 Univariable and multivariable analysis of predictors of self-reported hypertension among seafarers (n=4318)

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.

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 pseudo-R^2=0.379 reveal that predictors significantly influence a 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-R^2 value, the stronger the predictive power of the model. In this case, the Nagelkerke R^2 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-R^2 statistics, it is important to note that they do not have the same interpretation as R^2 in linear regression. Pseudo-R^2

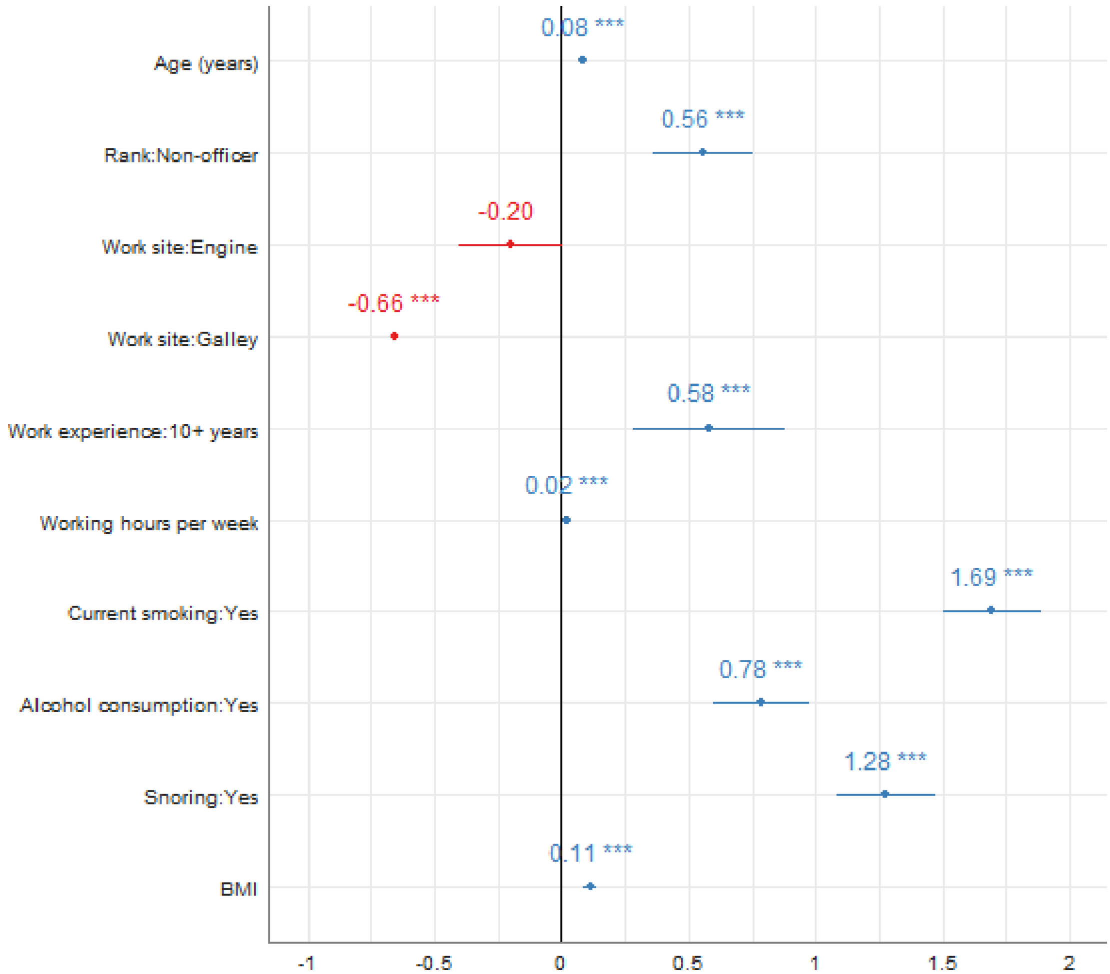

Figure 1 Forest plot of regression coefficients and their 95% CI for multiple logistic regression analysis of self-reported hypertension among seafarers. ***p<0.001. BMI, body mass index.

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). 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.[1 6 28–30] 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.[4 28] 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.[31 32] 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.[30] Another study conducted among Danish seafarers found that non-officers were more likely than officers to smoke every day.[33] 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. 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.[34]

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

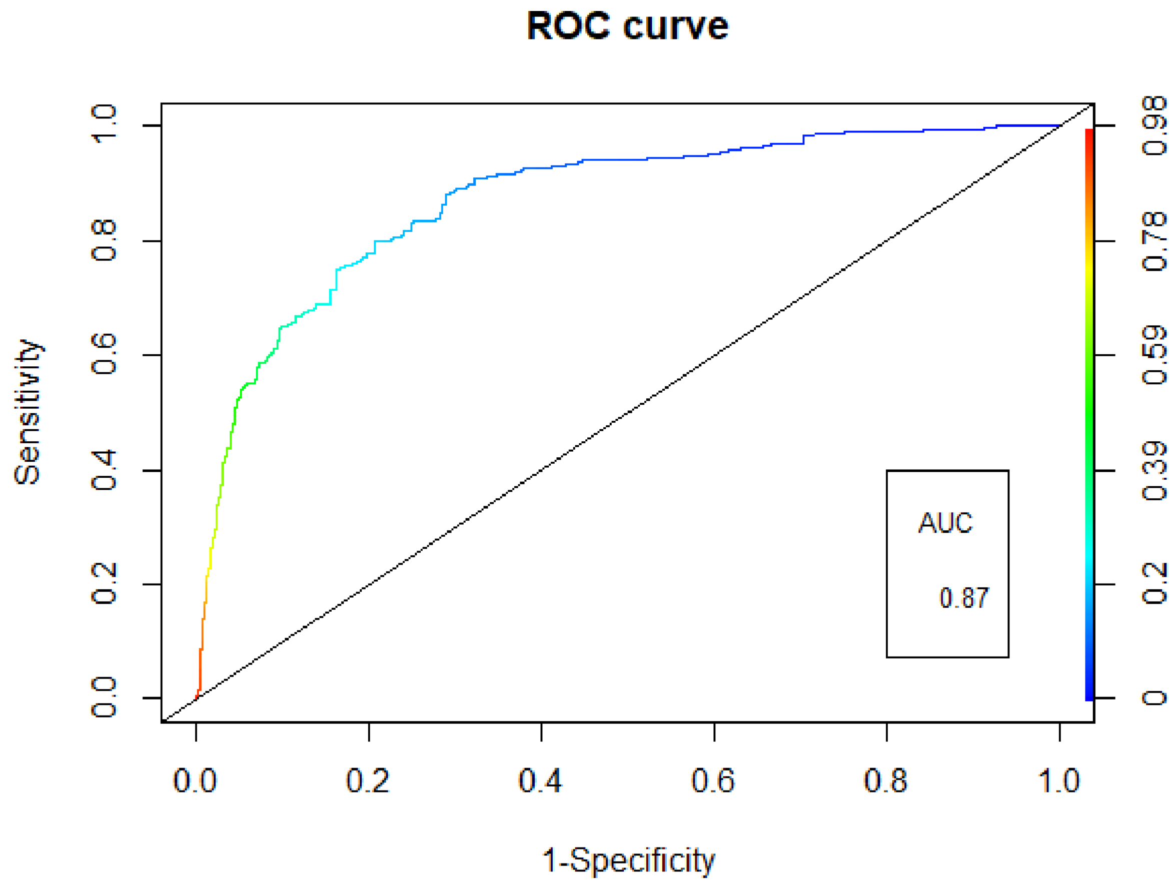

Figure 2 Receiver operating characteristic (ROC) curve of final a risk prediction model for seafarers with self-reported hypertension.

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). 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.[35] 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.[35] 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).[4] In contrast, the study conducted among seafarers on German-flagged ships reported that working hours were not significantly associated with coronary risk factors.[36] 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.[37] 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.[36] 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%)).[4] 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.[38] 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.[31 32] In a study conducted among industrial workers, it was found that work-related stress was associated with hypertension.[39] 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.[40] 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.[41] 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 participants, 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.[42–44] 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 kilometres from the nearest healthcare facility. Therefore, 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 (online supplemental figure 1). 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-organised 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, behavioural 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,[45] but it has not yet been implemented on a practical basis. It is, therefore, crucial that responsible bodies such as shipping companies, international maritime organisation, 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.

Limitations of the study

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 minimise 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 hypertension 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 hypertension 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 taken into account 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.

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 are in need of 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 centre doctors or other healthcare providers to predict hypertension during teleconsultations. These findings may be beneficial in furthering our understanding 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.

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Patient consent for publication Consent obtained directly from patient(s).

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Review

The Magnitude of Cardiovascular Disease Risk Factors in Seafarers from 1994 to 2021: A Systematic Review and Meta-Analysis

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Abstract: Objectives: The incidence of acute cardiac events is one of the main reasons for medical consultation, disembarkation, repatriation, and death among seafarers at sea. Managing cardiovascular risk factors, particularly those that can be modified, is the key to preventing cardiovascular disease. Therefore, this review estimates the pooled prevalence of major CVD risk factors among seafarers. Methods: We conducted a comprehensive search of studies published between 1994 and December 2021 in four international databases, namely PubMed/Medline, Scopus, Google Scholar, and Web of Science (WOS). Each study was evaluated for methodological quality using the Joanna Briggs Institute (JBI) critical appraisal tool for prevalence studies. The DerSimonian–Laird random-effects model with logit transformations was used to estimate the pooled prevalence of major CVD risk factors. The results were reported in accordance with the Preferred Items for Systematic Review and Meta-analysis (PRISMA) guidelines. Results: Out of all 1484 studies reviewed, 21 studies with 145,913 study participants met the eligibility criteria and were included in the meta-analysis. In the pooled analysis, the prevalence of smoking was found to be 40.14% (95% CI: 34.29 to 46.29%) with heterogeneity between studies (I^2 = 98%, $p < 0.01$). The prevalence of hypertension, overweight, obesity, diabetes mellitus, and alcohol consumption was 45.32%, 41.67%, 18.60%, 12.70%, and 38.58%, respectively. However, the sensitivity analysis after excluding studies showed a pooled prevalence of hypertension, overweight, obesity, and diabetes mellitus of 44.86%, 41.87%, 15.99%, and 16.84%, respectively. The subgroup analysis demonstrated that smoking prevalence among seafarers had decreased significantly after 2013. Conclusion: This study demonstrated that CVD risk factors, particularly hypertension, overweight, smoking, alcohol consumption, and obesity, are prevalent among seafarers. These findings may serve as a guide for shipping companies and other responsible bodies in order to prevent CVD risk factors among seafarers. PROSPERO Registration: CRD42022300993.

Keywords: hypertension; overweight; obesity; smoking; epidemiology; prevalence; seafarers; ships

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1. Introduction

Globally, cardiovascular diseases (CVD) account for the majority of disease burden and are attributed to both modifiable and unmodifiable risk factors [1]. CVD are also the number one cause of death from disease on board among seafarers [2,3]. On board a ship, acute cardiac events are one of the leading causes of medical consultation, disembarkation, repatriation, and mortality among seafarers [4–8]. The risk of cardiovascular events among seafarers is higher than that of the general population [9,10]. This may be due to a variety of reasons, including inadequate treatment, no regular monitoring, no immediate response to the emergency despite its severity, delayed resuscitation action, or work-related stress [11].

It is well known that the working conditions of sailors influence their health. A seafarer's work is characterized by long working hours, lack of sleep and frequent interruptions in their sleep, as well as staying at sea for extended periods of time, which adversely affects their health [12–14]. Due to the particular circumstances of their working environment, seafarers can experience different coping strategies such as unhealthy lifestyles (such as smoking, alcohol consumption, etc.) [13,15]. In addition to physical and psychological stresses, these unhealthy lifestyles contribute to CVD on board ships [16]. In order to prevent CVD, risk factors, particularly those that are modifiable, need to be managed.

Modifiable risk factors, such as tobacco use, heavy alcohol consumption, overweight/obesity, and physical inactivity are highly prevalent among seafarers [9,10,17–19]. Additionally, the prevalence of modifiable risk factors varies widely among mariners. In a recent systematic review, the prevalence of modifiable risk factors was reported; for smoking, the prevalence was between 37.3% and 72.3%, for overweight between 27.9% and 66.5%, for high blood pressure between 8.2% and 49.7%, and for diabetes mellitus, it ranged from 3.3% to 9.3% [20]. Another systematic review found that the prevalence of alcohol consumption among seafarers varies widely, from 11.5% to 89.5% [21]. As a result, the data presented on the prevalence of modifiable CVD risk factors among seafarers are inconsistent between studies. Inconsistent data on the prevalence of modifiable risk factors for CVD among seafarers may lead decision-makers as well as researchers to consider different figures based on their preferences and the available information. To date, no studies have been reported on the pooled prevalence of CVD risk factors in seafarers. In order to make evidence-based decisions, an analysis of the pooled prevalence of major risk factors for CVD is essential.

The present study aimed to estimate the prevalence of major CVD risk factors (cigarette smoking, high blood pressure, diabetes mellitus, overweight, obesity, and alcohol consumption) among seafarers by reviewing literature available on the topic and analyzing it with a meta-analysis prevalence approach. The results of this study could help international organizations [e.g., International Maritime Organization (IMO), International Labor Office (ILO), World Health Organization (WHO)], national governments, trade unions, shipping companies, and other decision-makers to develop strategies to improve the control of CVD risk factors on board ships among seafarers.

2. Methods

The present systematic review followed the Preferred Items for Systematic Review and Meta-analysis (PRISMA) checklists and diagrams to design and report the results [22], and registered a protocol for this review with the International Prospective Register of Systematic Reviews (PROSPERO) registration number: CRD42022300993).

It is available from https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42022300993 (accessed on 8 May 2023).

2.1. Research Questions

This study was guided by the following primary research questions: What is the magnitude of major CVD risk factors among seafarers? Does the distribution of CVD risk factors on-board ships differ according to the time period? How does age affect the distribution of CVD risk factors?

2.2. Search Strategy and Data Sources

In order to identify relevant studies, we conducted a comprehensive systematic search of the literature according to the Meta-Analysis of Observational Studies in Epidemiology (MOOSE) guidelines [23] and the PRISMA statement [22]. We searched the following databases PubMed/Medline, Scopus, Google Scholar, and Web of Science (WOS) for studies reporting the prevalence of CVD risk factors, specifically smoking, high blood pressure, diabetes mellitus, overweight, obesity, and alcohol use, up to November 2021. Further relevant articles were manually reviewed from the retrieved study reference lists. We applied the following key terms for searching in PubMed, Scopus, and WOS for hypertension: "prevalence", "proportion", "magnitude", "high blood pressure", "hypertension", "seafarers", "onboard ships", "merchant ships", and "sailors". To combine the search terms for each outcome of interest, we used Boolean operators such as "AND" and "OR". The full search strategy in PubMed and Scopus for the prevalence of hypertension, overweight, obesity, smoking, diabetes mellitus, and alcohol use can be found in Supplemental Table S1 (see Supplementary Table S1).

2.3. Inclusion and Exclusion Criteria

The following criteria were considered for eligibility: (1) observational studies (cross-sectional, cohort, and case-control); (2) studies reporting on the prevalence of high blood pressure, overweight, obesity, smoking, diabetes mellitus (DM), and alcohol consumption; (3) studies published between 1994 and December 2021; (4) full-text studies written in English. The following studies were not considered in this study: (1) studies that were not peer-reviewed or were unpublished; (2) studies published as abstracts or conference proceedings; (4) qualitative studies; (5) studies with a small sample size (less than 50 study participants); (6) studies published in languages other than English; (7) review studies, i.e., either systematic or narrative reviews.

In this study, six co-authors (G.G.S., U.A., C.M., G.N., A.S., and G.B.) carried out a literature search and selected the studies independently based on the inclusion criteria. While conducting the literature search and selecting the studies, the two senior co-authors (G.R. and F.A.) resolved any disagreements between the authors.

2.4. Data Extraction and Outcome Variables

After selecting studies, the variables extracted from each study were the first author's name, publication year, number of cases or reported prevalence, sample size, and study design. These data were entered into an Excel spreadsheet. The primary outcome of the present study was the pooled prevalence of CVD risk factors (high blood pressure, smoking, diabetes, overweight, obesity, alcohol consumption). The five authors (G.G.S., U.A., C.M., G.N., and G.B.) extracted data and compared the results. Any discrepancies between the results were resolved through discussion.

2.5. Quality Assessment

The Joanna Briggs Institute (JBI) critical appraisal tool was used to assess the methodological quality of the studies [24]. The critical appraisal tool contains ten items that were used to evaluate the methodological quality of studies reporting prevalence data (see Supplementary Table S2). A critical appraisal was performed prior to data extraction. Despite the fact that there are four possible responses to each question in the critical appraisal tool ("yes", "no", "unclear" or "not applicable"), there is no indication in the document as to how the assessment tool should be interpreted quantitatively in order to rank the studies as low or high quality. Some studies, however, used the mean scores to measure the quality of studies [25,26].

In the present study, the quality of the studies was evaluated using agreed-upon category scores for each study. As a result, the studies were categorized into low, medium, and high quality based on scores ranging from 0 to 10. The studies scoring between 0 and 4 were considered low-quality, the studies scoring between 5 and 6 were considered medium-quality, while studies scoring seven and above (7–10) were considered high-quality.

2.6. Statistical Analysis

The data were entered into a Microsoft Excel spreadsheet version 2019 and analyzed using R-software (Version 4.1.1, The R Foundation for Statistical Computing, Vienna, Austria) [27]. We used the metaprop()functions from R package meta [28] for prevalence and summary meta-analysis and we employed also the *escalc()*, *rma()*, and *predict()* functions from R package metafor [29] along with different arguments to calculate individual effect size (i.e., proportions) and their corresponding sampling variance estimation. A DerSimonian–Laird random-effects model with logit transformations was used to estimate the pooled prevalence of CVD risk factors (high blood pressure, smoking, overweight, obesity, diabetes mellitus, and alcohol consumption) [30]. A random-effect model was used to adjust observed variability [31]. The pooled proportion of each CVD risk factor, considered in the present study with a 95% CI, was generated and visualized using a forest plot.

Begg's and Egger's tests were performed to detect the potential publication bias [32,33]. Heterogeneity between studies was assessed using the Cochran's Q test [34] and I2 test statistics [35]. The degree of heterogeneity was considered as low, moderate, and high based on I^2 values of less than 25%, 25% to 75%, and more than 75%, respectively [36]. A univariate meta-regression analysis was conducted based on publication years and sample size to estimate their impact on the prevalence of each CVD risk factor. We also performed a sensitivity analysis using the "Leave-one-out" analysis with a built-in function. Once the outliers were identified, we re-estimated the summary effect (i.e., pooled prevalence) by omitting outliers. Subgroup analyses were also performed according to the year of publication.

3. Results

3.1. Study Characteristics

In total, 1484 records were identified using our search strategy, of which 954 records were excluded because of duplicates. The title and abstract screening excluded 495 articles. The remaining 35 full-text articles were evaluated. Among the 35 full-text papers reviewed, 21 studies with 145,913 study participants met the eligibility criteria and were included in the meta-analysis [9,10,17,37–54]. Figure 1 shows the entire process of finding, selecting, and including studies (Figure 1).

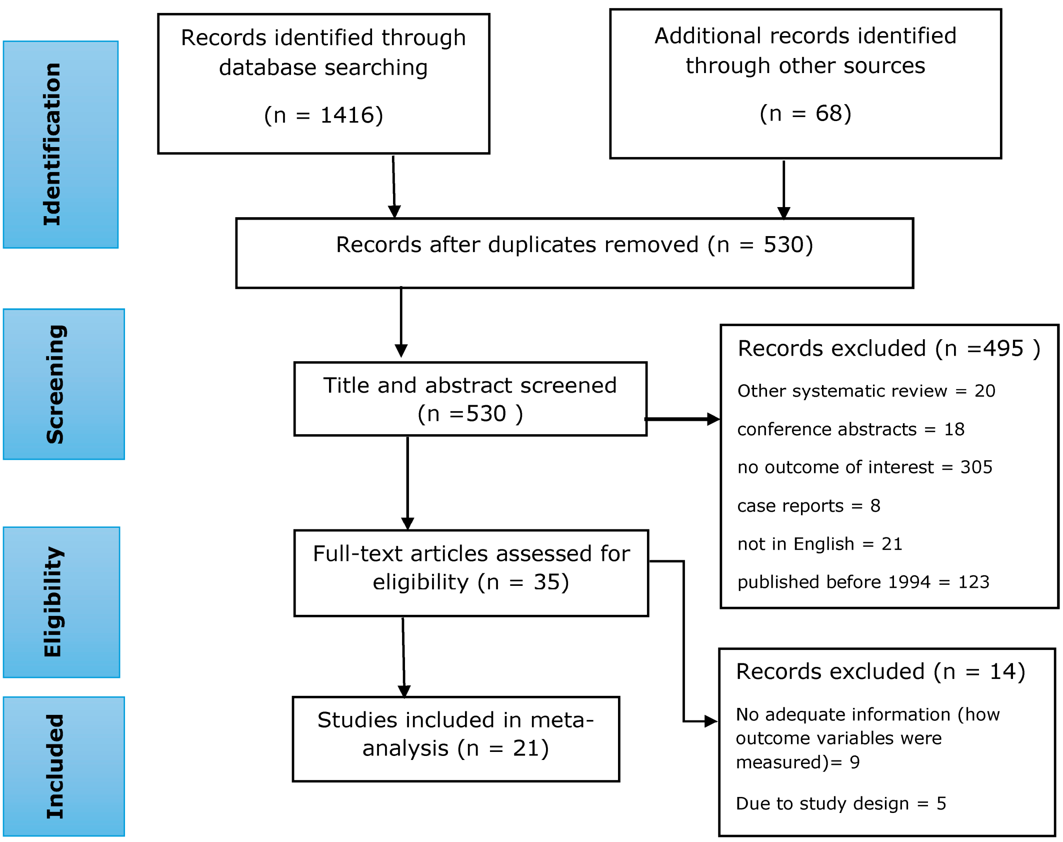

Figure 1. A flow diagram showing the process of study searching, selection, and inclusion in the present systematic review and meta-analysis.

The studies included in the present systematic review and meta-analysis were conducted between 1994 and 2021. All the included studies were cross-sectional studies (out of 21 studies, 3 were retrospective analyses of cross-sectional studies). The characteristics of the selected studies are summarized in Table 1 along with their methodological quality assessment (Table 1).

Table 1. Characteristics of selected studies for systematic review and meta-analysis.

Author Name and Year	Study Design	Sample Size	Prevalence (%)						Quality Score
			HBP	Smoking	Diabetes Mellitus	Overweight	Obesity	Alcohol Use	
Hansen, H.L., et al., 1994 [10]	Cross-sectional	390	NA	67.2	NA	51.6	16.1	NA	7
Kirkutis, A., et al., 2004 [9]	Cross-sectional	1135	44.9	55.2	NA	NA	NA	82.6	9
Hoeyer, J.L., et al., 2005 [37]	Retrosp. Cross-sectional	1257	NA	NA	NA	41	22.9	NA	8
Oldenburg, M., et al., 2008 [38]	Cross-sectional	161	49.7	37.3	5	41.6	21.7	73.9	9
Fort, E., et al., 2009 [39]	Cross-sectional	1847	NA	44	NA	NA	NA	NA	6
Fort, E., et al., 2010 [40]	Cross-sectional	1068	NA	41.4	NA	NA	NA	8.0	9
Purnawarma, I., et al., 2011 [41]	Cross-sectional	212	21.2	47.6	3.3	42.5	10.4	NA	7
Scovill, S.M., et al., 2012 [42]	Cross-sectional	387	42	41	22	28	61	NA	7
Møller Pedersen, S.F., et al., 2013 [43]	Cross-sectional	524	70.4	30.6	17.9	NA	NA	18.6	4
Hjarnoe, L., et al., 2014 [17]	Cross-sectional	272	48	44	NA	50	25	NA	5
Nas, S., et al., 2014 [44]	Retrosp. Cross-sectional	131,152	NA	NA	NA	39.6	12.5	NA	4
Aapaliya, P., et al., 2015 [45]	Cross-sectional	385	NA	25.2	NA	NA	NA	14.3	4
Mingshan, T., et al., 2016 [46]	Cross-sectional	629	44.7	23.9	NA	38.3	17.3	71.9	7
Mahdi, S.S., et al., 2016 [47]	Cross-sectional	2060	NA	56.11	NA	NA	NA	11.5	5
Baygi, F., et al., 2016 [48]	Cross-sectional	234	42.3	27.8	23.1	42.5	8.6	NA	6
Gregorio, E.R., et al., 2016 [49]	Cross-sectional	136	NA	36.0	NA	NA	NA	79.4	5
Sliškovíc, A., et al., 2017 [50]	Cross-sectional	530	NA	42.0	NA	NA	NA	41.7	6
Westenhoefer, J., et al., 2018 [51]	Cross-sectional	81	NA	NA	NA	40.7	34.6	NA	5
Grappasonni, I., et al., 2019 [52]	Cross-sectional	1478	NA	28.9	NA	NA	NA	19.5	9
Nittari, G., et al., 2019 [53]	Retrosp.cross-sectional	1155	NA	NA	NA	40.8	11.2	NA	5
Neumann, F.A., et al., 2021 [54]	Cross-sectional	820	NA	NA	NA	45.8	9.8	NA	8

NA = Not Assessed/not assessed according to WHO/IDF criteria [High Blood pressure (HBP), overweight, obesity, Diabetes Mellitus (DM)], and alcohol consumption.

3.2. Operational Definition of Outcome Variables in the Included Studies

Four studies defined high blood pressure/hypertension according to the current World Health Organization (WHO) criteria [55]: systolic blood pressure (SBP) $\geq$ 140 mmHg and/or diastolic blood pressure (DBP) $\geq$ 90 mmHg and/or taking antihypertensive drugs. In the remaining four studies, high blood pressure was defined as a SBP $\geq$ 130 mmHg and/or a DBP $\geq$ 85 mmHg or antihypertensive medication. Smoking status (n = 16) was assessed using a self-reported questionnaire. It was subsequently verified by asking questions such as about the duration of use, age at onset, and the number of cigarettes per day. Overweight (n = 12) and obesity (n = 12) were defined according to current WHO criteria using body mass index (BMI) [56]: 25.0 kg/m^2 $\leq$ BMI < 30.0 kg/m^2, and $\geq$30 kg/m^2, respectively, and the BMI was also calculated as weight in kilograms (kg) divided by height in meters (m) squared [Weight (kg)/Height (m)^2]. Regarding diabetes mellitus, it was defined as follows: fasting plasma glucose level $\geq$ 110 mg/dL (n = 1), fasting blood glucose level > 126 mg/dL or blood glucose level 2 h after eating > 200 mg/dL (n = 1), fasting plasma glucose $\geq$ 5.6 mmol/L or previously diagnosed type two diabetes (n = 1), and fasting glucose level $\geq$ 110 mg/dL and/or anti-diabetic medication use (n = 2).

3.3. Prevalence of CVD Risk Factors

3.3.1. Prevalence of Smoking

Sixteen studies were selected with a total of 11,511 study participants [9,10,17,38–43,45–50,52]. In general, the prevalence of smoking varied greatly between the 16 studies, ranging from 23.85% [46] to 67.18% [10]. The pooled prevalence of smoking among seafarers was found to be 40.14% (95% CI: 34.29% to 46.29%), with a high and statistically significant heterogeneity (I^2 = 98%, p < 0.01). We took into account the year of publication as a subgroup analysis of smoking prevalence. Thus, seven studies were published between 1994 and 2012, and nine studies were published between 2013 and 2020. The publication year was then categorized into two groups: 2013 and after (2013–2021), and before 2013 (1994–2012). As a result, the pooled proportion of smoking was 34.43% (95% CI: 25.90% to 44.11%, I^2 = 98%, p < 0.01) during the 2013 year of publication and after, and 47.85% (95% CI: 41.24% to 54.52%, I^2 = 95%, p < 0.01) before 2013. There was a significant decline in smoking prevalence (p < 0.01) in 2013 and subsequent years compared to before 2013 (34.43% vs. 47.85%) (Figure 2).

The findings of univariate meta-regression analysis showed that sample size had no impact on the prevalence of smoking among seafarers [QM (test of moderators) (1) = 0.956, p = 0.328]. The year of publication had an impact on the observed prevalence of smoking in seafarers. In fact, there was an association between the prevalence of smoking and year of publication (QM(1) = 9.648, p < 0.001) as well as the significant slope coefficient [−0.059, $Z(14) = -3.106$, p = 0.002]. The R^2 for the publication year shows that 20.47% of the true heterogeneity in the presented effect size can be explained by the year of publication.

The sensitivity analysis indicated no evidence of outliers among the included studies for smoking prevalence (see Supplementary Tables S3 and S4).

3.3.2. Prevalence of High Blood Pressure

The pooled prevalence of high blood pressure among seafarers was 45.32% (95% CI: 36.98% to 53.93%) with significant heterogeneity between the studies (I^2 = 96%, p < 0.01) (Figure 3). Overall, eight studies were identified with a total of 3554 study participants [9,17,38,41–43,46,48]. The prevalence of high blood pressure varied between the selected studies, ranging from 21.23% [41] to 70.42% [43]. As for the prevalence based on the year of publication, the overall proportion of prevalence of high blood pressure (HBP) was 51.74% (95% CI: 37.90% to 65.32%) after the 2013 year of publication, and 39.02% (95%CI: 29.85 to 49.03%) before 2013 (Figure 3).

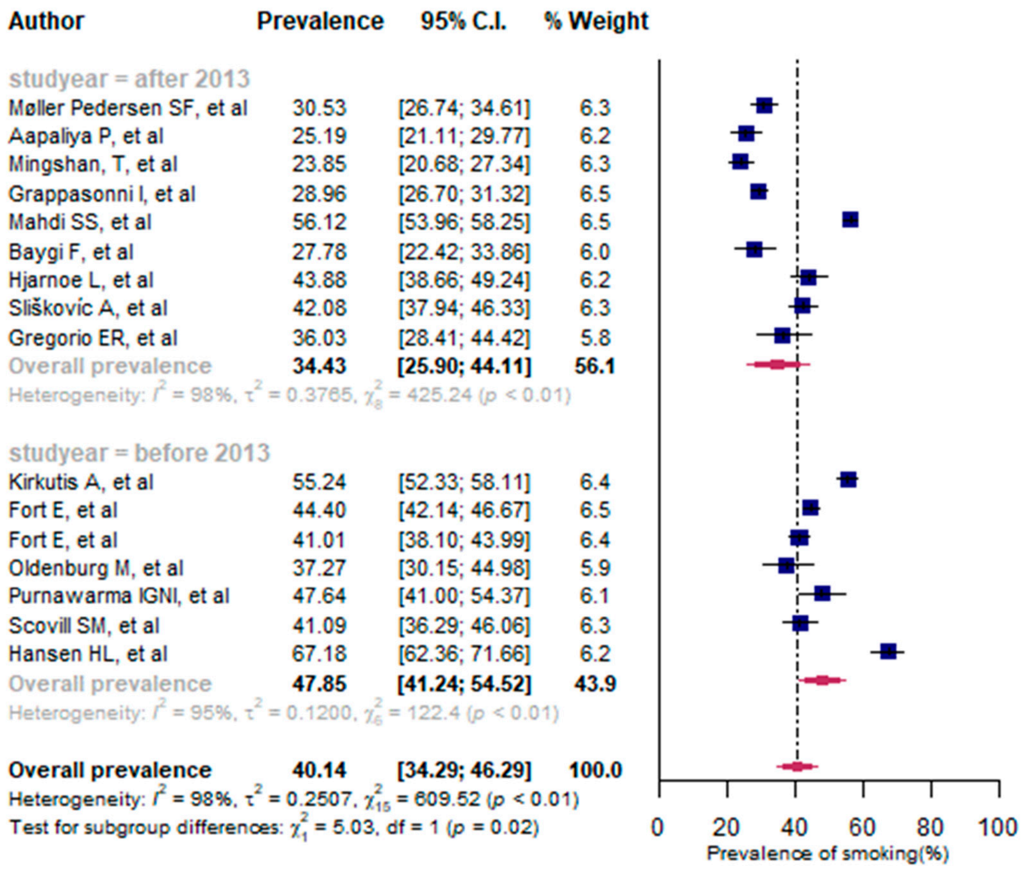

Figure 2. A forest plot of the prevalence (%) of smoking among seafarers using a random-effects model.

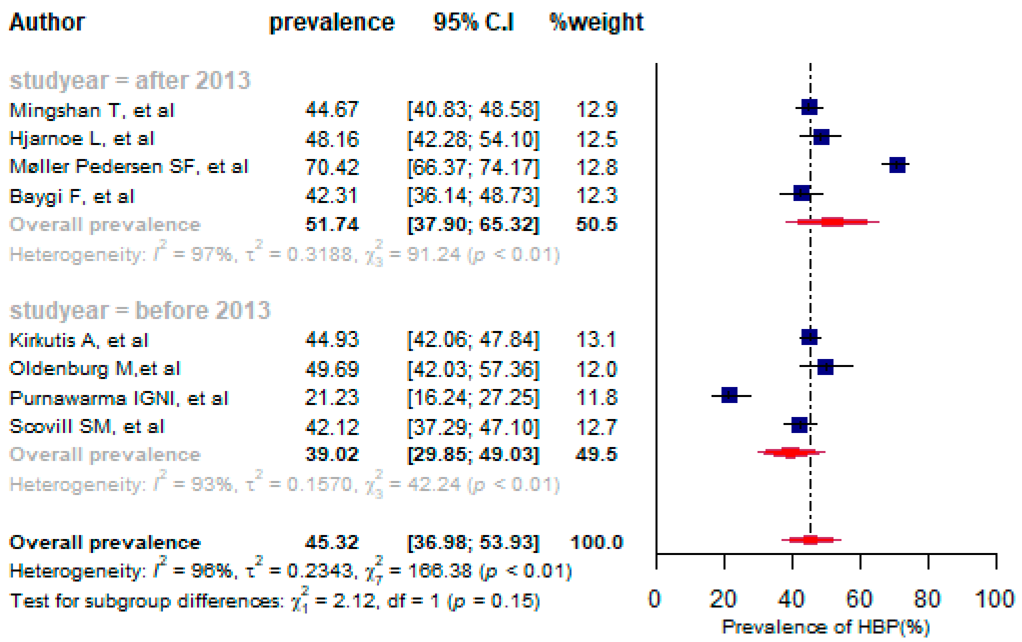

Figure 3. A forest plot of the prevalence (%) of high blood pressure among seafarers using a random-effects model.

A sensitivity analysis was performed and two outlier studies were identified [41,43], which influenced the pooled estimate of high blood pressure (see Supplementary Tables S5 and S6). After omitting the outlier studies, the overall prevalence of high blood pressure was 44.86% (95%CI: 43.03% to 46.71%) (Supplementary Figure S1), which indicates that the pooled prevalence decreased slightly after removing the outlier studies.

3.3.3. Prevalence of Overweight

Overall, twelve studies reporting the overweight prevalence with a total of 136,710 participants were selected for the meta-analysis [10,17,37,38,41,42,44,46,48,51,53,54]. In selected studies, the prevalence of overweight varied from 28.09% [42] to 51.51% [10]. The pooled prevalence of overweight among seafarers was 41.67% (95% CI: 39.16% to 44.22%, $I^2 = 85\%$, $p < 0.01$). Five of the twelve studies analyzed for combined prevalence were published before 2013 and the remaining seven studies were published after 2013. As a result, the pooled proportion of overweight before the 2013 year of publication was found to be 40.71% (95% CI: 33.67% to 48.16%), and it was 42.15% (95% CI: 39.46% to 44.88%) after 2013. Thus, the prevalence of overweight increased slightly after 2013 compared to before 2013, although the difference was not statistically significant ($p = 0.72$) (Figure 4).

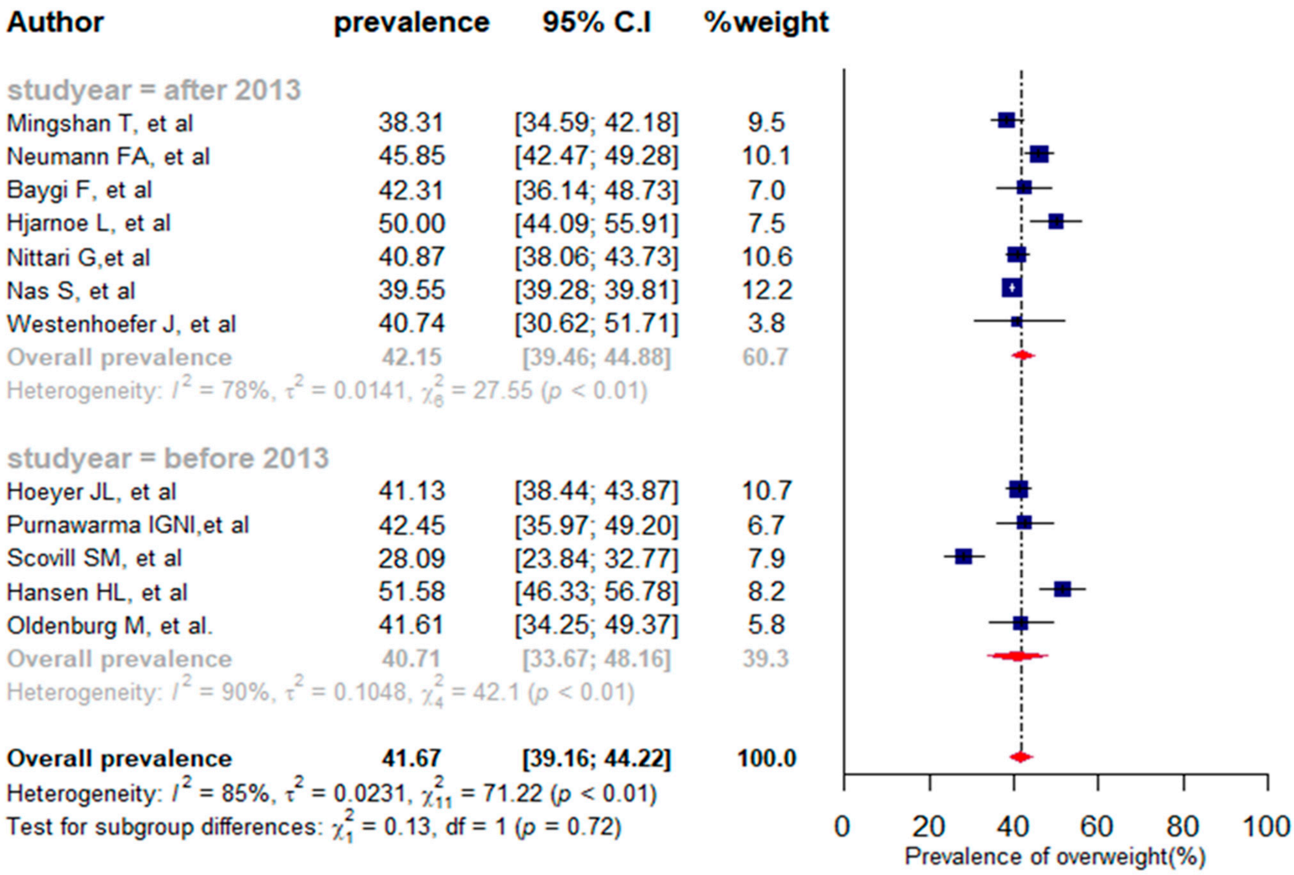

Figure 4. A forest plot of the prevalence (%) of overweight among seafarers using a random-effects model.

The meta-regression analysis indicated that both sample size [QM(1) = 0.209, $p = 0.647$] and publication year [QM(1) = 1.495, $p = 0.222$] were not significantly associated with the proportion of high blood pressure. The sensitivity analysis identified two studies that had influenced the overall prevalence of overweight (Supplementary Tables S7 and S8). After removing the two outlier studies [10,42], the pooled prevalence of overweight was 41.87% (39.88% to 43.89%) with heterogeneity between studies ($I^2 = 70\%$, $p < 0.01$) (see Supplementary Figure S2).

In two studies, the prevalence of overweight was assessed by age group [37,44]. As a result, the overall prevalence of overweight among seafarers aged 16–24 years was 25.64% (95% CI: 18.43% to 34.48%), and 48.84% (95% CI: 43.66% to 54.04%) among those aged

45–66 years (Table 2). The results of our study demonstrated that overweight in seafarers increases significantly with age ($x^2(2) = 18.46$, $p < 0.001$).

Table 2. Prevalence of overweight and obesity in terms of age among seafarers.

	Age Group (Years)	Pooled Prevalence (95% CI)	I^2 (*p*-Value)
Overweight	16–24	25.64% (18.43–34.48)	77% (0.04)
	25–44	41.49% (37.25–45.86)	80% (0.03)
	45–66	48.84% (43.66–54.04)	84% (0.001)
Obesity	16–24	5.10% (2.05–12.10)	87% (0.001)
	25–44	15.14% (10.30–21.69)	95% (0.001)
	45–66	26.74% (20.13–34.59)	94% (0.001)

3.3.4. Prevalence of Obesity

We included 12 studies reporting data on obesity in the present meta-analysis, with a total of 136,710 subjects [10,17,37,38,41,42,44,46,48,51,53,54]. In selected studies, obesity prevalence varied widely, ranging from 8.55% [48] to 61.08% [42]. The pooled prevalence for obesity was 18.60% (95% CI: 13.24% to 25.48%, $I^2 = 99\%$, $p < 0.01$). As for the years of publication, seven studies were published after 2013, and five studies before 2013. Regarding publication-year-specific prevalence, the combined proportion of obesity after 2013 was 15.14% (95% CI: 11.93% to 19.03%), and 23.84% (95%CI: 11.61% to 42.72%) before 2013. The magnitude of obesity before 2013 was higher than after 2013 (23.84% vs. 15.14%), but the difference was not statistically significant ($p = 0.23$) (Figure 5).

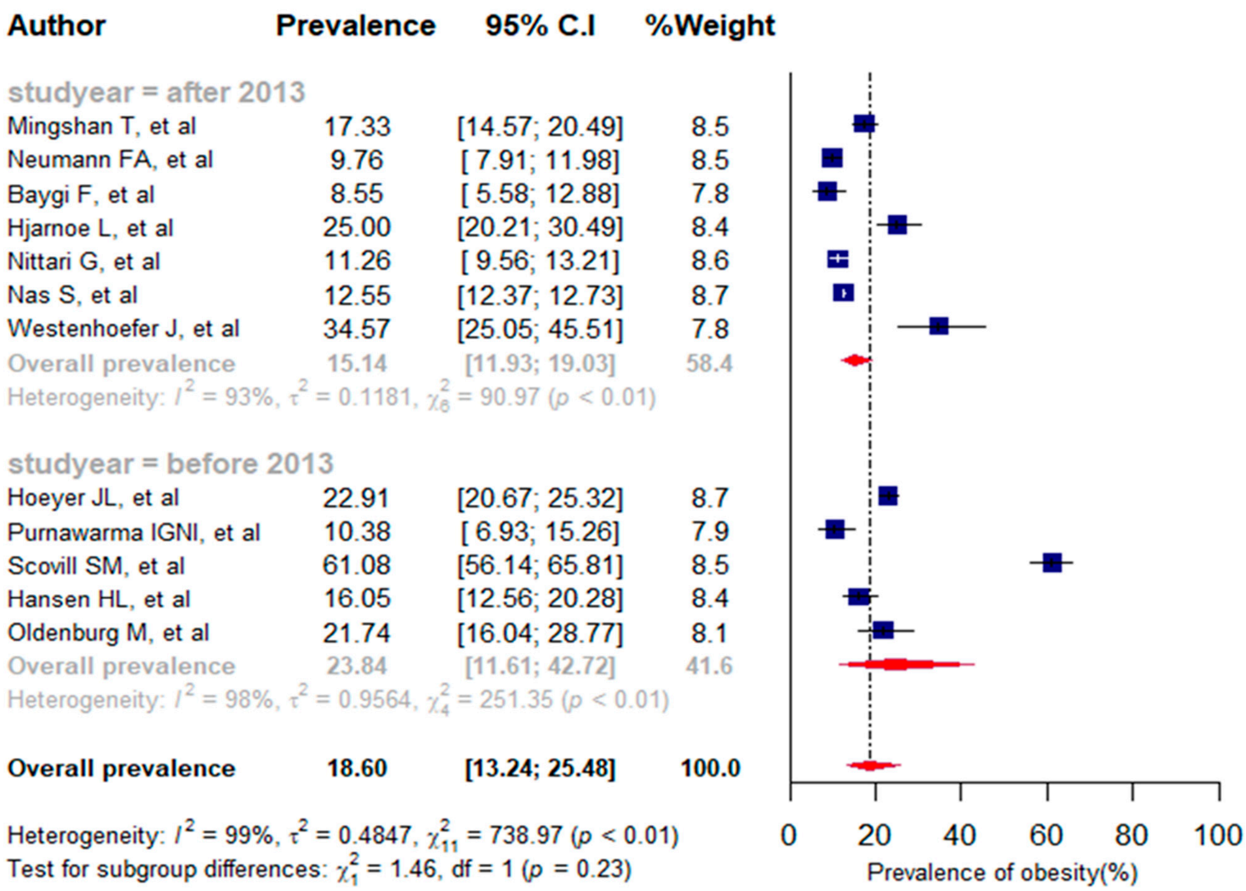

Figure 5. A forest plot of the prevalence (%) of obesity among seafarers using a random-effects model.

Among the 12 studies included in the meta-analysis for the prevalence of obesity in seafarers, only 2 studies [37,44] reported the obesity prevalence stratified by the age group of the seafarers. As a result, the pooled prevalence of obesity among seafarers aged from 16 to 24 years was 5.10% (95%CI: 2.05% to 12.10%), and 26.74% (95%CI: 20.13% to 34.59%) in seafarers aged between 45 and 66 years (Table 2). According to these findings, obese seafarers aged 45 to 66 years had a higher prevalence, and the difference between the age groups was statistically significant as well (X^2 (2) = 16.37, $p < 0.001$).

According to the univariate meta-regression analysis results, both sample size [QM(1) = 0.344, $p = 0.557$] and publication year [QM(1) = 0.280, $p = 0.596$] were not significantly associated with the proportion of obesity. By conducting sensitivity analysis, one outlier study was identified (Supplementary Tables S9 and S10), which influenced the pooled prevalence of obesity. After omitting the outlier study [42], the overall prevalence of obesity was found to be 15.99% (95% CI: 12.88% to 19.68%), with substantial heterogeneity between studies (I^2 = 95%, $p < 0.01$) (Supplementary Figure S3).

3.3.5. Prevalence of Diabetes Mellitus

A total of 1519 participants were included in five studies that investigated the prevalence of diabetes mellitus [38,41–43,48]. The overall proportion of diabetes mellitus in the five studies included in the meta-analysis varied from 3.30% [41] to 23.08%. The pooled prevalence for diabetes mellitus was 12.70% (95%CI: 7.88% to 19.85%, I^2 = 92%, $p < 0.001$). Among the five studies, three studies were published before 2013 and the remaining two studies were published after 2013. The combined proportion for diabetes mellitus from papers published after 2013 was 20.10% (95%CI: 15.60% to 25.51%, I^2 = 63%, $p < 0.01$). However, the prevalence of DM before 2013 was 7.62% (95%CI: 1.84% to 26.69%, I^2 = 95%, $p < 0.01$) (Figure 6).

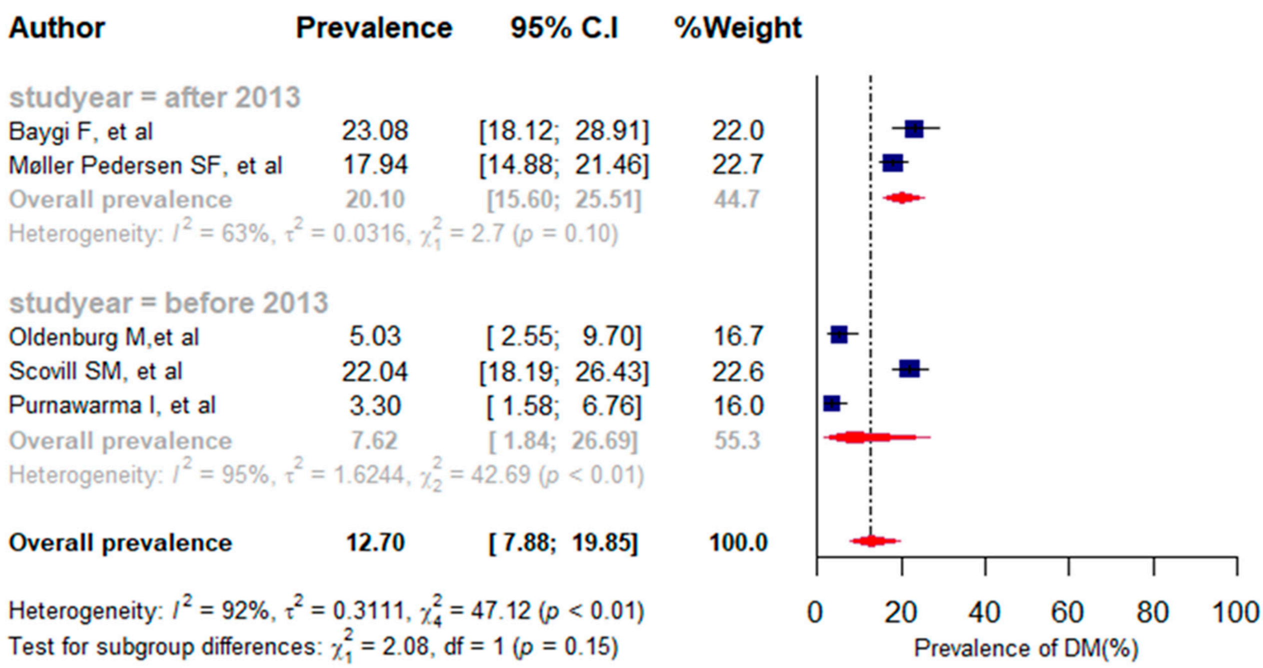

Figure 6. A forest plot of the prevalence (%) of diabetes mellitus among seafarers using a random-effects model.

Using sensitivity analysis, one outlier study was identified (Supplementary Tables S11 and S12). After excluding the outlier study [41], the combined prevalence of diabetes mellitus (DM) was 16.84% (11.75% to 23.53%, I^2 = 86%, $p < 0.01$) (Supplementary Figure S4). Consequently, the overall prevalence of DM was increased after omitting the outlier study.

3.3.6. Prevalence of Alcohol Consumption

A total of ten studies with 8093 participants provided data on alcohol consumption prevalence [9,38,40,43,45–47,49,50,52]. Overall, among the ten studies included in the meta-analysis, alcohol consumption proportion varied widely, ranging from 8.05% [40] to 82.56% [9]. A pooled prevalence of alcohol consumption was 38.56% (95%CI: 19.68% to 61.69%, I^2 = 100%, $p < 0.001$) (Supplementary Figure S5). In terms of the publication years, seven studies were published after 2013, and three studies were published before 2013. Taking into account publication-year-specific prevalence, alcohol use prevalence after 2013 was 33.42% (95% CI: 17.11% to 54.98%), and 51.32% (95%CI: 6.48% to 94.14%) before 2013. The prevalence of alcohol use before 2013 was higher than after 2013 (51.32% vs. 33.42%), but the difference was not statistically significant (p = 0.61) (Supplementary Figure S5).

We conducted a sensitivity analysis in order to identify outliers among the included studies in the meta-analysis. The sensitivity analysis, however, did not reveal any evidence of outliers among the included studies (see Supplementary Tables S13 and S14).

3.4. Publication Bias

As for the publication bias, neither Egger's (p = 0.690) nor Begg's (p = 0.571) tests were statistically significant, indicating that no publication bias occurred.

4. Discussion

In the present systematic review and meta-analysis, we estimated the magnitude of CVD risk factors (smoking, high blood pressure, overweight, obesity, diabetes mellitus, and alcohol consumption) among seafarers. We synthesized the findings of 21 published studies with a total of 145,913 study participants between 1994 and 2021 that met the eligibility criteria to estimate the prevalence of major CVD risk factors. We considered the literature from 1994 and onwards in our study search, since we did not find any relevant studies on CVD risk factor prevalence before 1994 based on our preliminary search of different worldwide databases when looking for studies on seafarers. In addition, we searched for peer-reviewed studies on CVD risk factor prevalence from 1994 until 31 December 2021, in the databases we selected because this study began in January 2022. As for the methodological quality assessment of the included studies, 14.3% (n = 3), 38.1% (n = 8), and 47.6% (n = 10) of the studies were of low, medium, and high methodological quality (Table 1). Among the major CVD risk factors considered in this study, high blood pressure (HBP) was the most common risk factor (45.32%), with high and significant heterogeneity (I^2 = 96%, $p < 0.01$). After the sensitivity analysis, HBP (44.86%) was also the main common CVD risk factor compared to the other risk factors included in this study. In a study conducted among seafarers, high blood pressure was identified as a leading cause of cardiovascular disease and accounted for 89% of all CVD diagnosed between 2010 and 2018 on board ships [57].

For the purpose of comparing the magnitude of CVD risk factors, we created two groups based on the study period (before and after 2013). The year 2013 was utilized as a cut-off point because different initiatives related to seafarers' health were implemented or amended in 2013 and thereafter [58,59]. Therefore, we were interested in studying changes in the magnitude of common CVD risk factors over time. According to the subgroup analysis, the pooled prevalence of HBP was higher after the 2013 year of publication than before 2013 (51.74% vs. 39.02%), indicating an increase in the magnitude of HBP on board ships. After 2013, different measures were undertaken to improve the health of seafarers at sea. As an example, the 2010 International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW) [58] and the 2006 Maritime Labor Convention (MLC) entered into force on 20 August 2013 [60]. The MLC 2006 outlined numerous health services for seafarers, including physical examination, health monitoring, mandatory limits on board ships, and lifestyle management. Nevertheless, CVD and its risk factors, most notably HBP, were estimated to be more prevalent among seafarers after 2013. Perhaps this is due to the ineffective implementation of measures specified by STCW 2010 and MLC 2006 in relation to the health protection of seafarers after 2013. On the other hand, the IMO, shipping companies, and other responsible bodies need to pay close attention to the implementation of the above conventions and health services for seafarers.

A study conducted on board ships reported that overweight and obesity increased, by 6.70 and 16.75 times, respectively, the risk of high blood pressure among seafarers [61]. Other studies also reported that the prevalence of high blood pressure increases with augmented body mass index, job duration at sea, working hours per week, and age of seafarers [9,62]. The application of specific interventions targeting risk factors such as weight management, limiting daily and weekly working hours in accordance with the MLC 2006 convention, and the regular monitoring and application of prevention measures targeting older seafarers would help to reduce the risk of high blood pressure on board ships.

In this study, we found overweight to be the second most prevalent modifiable risk factor for CVD in seafarers (41.67% with I^2 = 85%, $p < 0.01$). We performed the sensitivity analysis and omitted two outlier studies among the studies included in the meta-analysis for overweight prevalence. We then re-estimated the prevalence of overweight (41.87%) and it was slightly higher than the estimated prevalence before sensitivity analysis. Based on the subgroup analysis, the prevalence of overweight was found to be higher after the 2013 year of publication compared to before 2013 (42.15% vs. 40.71%). We also stratified the proportion of overweight by age group, and accordingly the prevalence of overweight significantly increased with an increase in the age of seafarers. The results obtained are consistent with previous studies conducted among seafarers [61,62]. The possibilities of physical activity on board ships are limited due to the working conditions and the lack of access to a gymnasium on some merchant ships at sea [37]. Consequently, overweight becomes one of the most prevalent risk factors for CVD and can cause relevant health problems at sea. To reduce body weight and the likelihood of CVD, preventive measures such as nutrition management, physical training, and gyms on board ships should be considered. The popularity and diffusion of gyms are increasing on modern cargo ships. It is imperative to follow a physical activity plan under the supervision of a physician and/or trainer in order to maximize the benefits of physical activity to prevent CVDs. During the pre-employment examination, body weight and BMI should be considered as relevant recruitment criteria for seafarers.

Smoking was found to be the third most common modifiable risk factor for CVD among seafarers in the present study (40.14%). Our study demonstrated that smoking was significantly reduced after 2013 compared to years before 2013 (34.43% vs. 47.85%). This could be due to the application of certain mandatory limits related to smoking on board ships and the awareness of the consequences of smoking among seafarers after 2013. Similarly, Pougnet R and his colleagues [20] reported that smoking prevalence was significantly lower in the 2000s compared to the 1990s (45.4% vs. 61.3%, $p < 0.01$). We encourage applying effective preventive measures and mandatory limits for other common risk factors also, such as high blood pressure, overweight, and alcohol consumption, in order to reduce their prevalence. In general, smoking prevalence is still higher among seafarers. Mandatory limits such as prohibiting smoking in some ship areas should be enforced to reduce the proportion of this phenomenon. Health promotion interventions such as conducting smoking cessation campaigns and raising awareness of the consequences of smoking would improve the control of cigarette smoking on board ships. A study conducted on board ships indicated that level of education is significantly correlated with smoking [52]. Hence, specific campaigns directed at the people more vulnerable in this respect should be considered. Another modifiable CVD risk factor prevalent among seafarers was alcohol consumption [38.56% (95%CI: 19.68% to 61.69%)]. Pooled alcohol consumption was lower after 2013 than before 2013, although the difference was not statistically significant (33.42% vs. 51.32%, $p = 0.61$). This reduction in alcohol use prevalence may be attributed to the update of preventive measures for alcohol and drug abuse by the International Maritime Organization (IMO) in 2010. For example, the International Maritime Organization (IMO) updated the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW Convention) in 2010 in order to address the issue of alcohol and drug abuse among seafarers [63]. The magnitude of alcohol consumption on board is still high, and responsible bodies, including the International Maritime Organization (IMO), shipping companies, and other stakeholders, need to develop mitigation strategies to reduce the prevalence of alcohol consumption among seafarers as it is a critical safety issue that should be addressed. The IMO should also evaluate whether the amended STCW convention regarding alcohol use has been fully implemented.

Obesity and diabetes mellitus were also important risk factors for CVD among seafarers. The estimated prevalence of obesity and diabetes mellitus was 18.60% and 12.70%, respectively. However, the sensitivity analysis, after omitting outliers, showed that the combined prevalence of obesity and diabetes mellitus was 15.99% and 16.84%, respectively. We found that the prevalence of obesity increased with the increasing age of seafarers. In addition, the highest prevalence of obesity was observed among older sailors [26.74%, with significant heterogeneity between studies (I^2 = 94%, p <0.001)]. Some shipping companies have taken body weight, particularly obesity, into account in their recruitment criteria. In the pre-employment examination of Danish seafarers, a BMI of 40 kg per square meter or more results in exclusion from working on board ships [64]. Norway too have introduced some limitations for the recruitment of seafarers with a BMI of 35 kg/m^2 or above [37]. Obesity not only increases the risk of diabetes mellitus, high blood pressure, and the burden of CVD, but also renders seafarers unfit for work on board ships. Seafarers often experience a sedentary lifestyle on board. Consequently, it is important to encourage regular exercise, to plan physical activity and health education through telemedicine, and to provide smart offline mobile applications to guide seafarers in improving their physical activity. Lifestyle changes such as physical activity, a healthy diet, and the availability of a gymnasium on board ships could positively influence the body weight of seafarers. The prevalence of diabetes mellitus has increased in parallel with the increase in work experience at sea, age, and weekly working hours. In other words, long job duration at sea, long working hours per week, and older age increase the risk of high blood glucose levels in seafarers [62].

4.1. Strengths and Limitations

This is the first review to estimate a pooled prevalence in the context of major risk factors for cardiovascular disease among seafarers at sea. We registered this review protocol initially with the International Prospective Register of Systematic Reviews (PROSPERO) and adhered to the PRISMA guidelines when designing, conducting, and reporting our findings to ensure the validity of the methods used.

Even though most of the included studies were of a low risk of bias, this review found substantial heterogeneity among the included studies, which affected the quality of the overall evidence. Perhaps this is due to poor methodological approaches employed by the various studies. There are a few studies on the health of seafarers centered on their cardiovascular diseases, and data on CVD risk factor prevalence are in general limited. Almost all of the studies included in this review were cross-sectional and some of them had poor methodological quality. In addition, we did not find studies that stratified the prevalence of modifiable CVD risk factors by the rank, nationality, and workplace of seafarers; therefore, we did not take into consideration rank, nationality, and worksite differences in the distribution of prevalence of risk factors for CVD. The magnitude of hypercholesterolemia was not considered in this study due to a lack of studies, despite being one of the major CVD risk factors. We, therefore, encourage future studies to take into account these variables and evaluate their prevalence in a pooled analysis. Despite the above limitations, the estimated proportion of the most common risk factors of CVD is relevant for evidence-based decision making, and for the development of prevention initiatives and control strategies to mitigate the burden of CVD at sea.

4.2. Implications for Practice

Modifiable risk factors are precursors to cardiovascular disease, which results in morbidity, mortality, and the need to divert ships from their intended course at sea. Seafarers experience more cardiovascular events than the general population. Moreover, the prognosis after CVD at sea is also worse than ashore [5]. Cardiovascular diseases have received less attention among maritime seafarers in comparison to the general population, although the magnitude of cardiovascular diseases at sea is growing. However, medical emergencies on all types of ships were caused most often by cardiovascular diseases [65]. It is estimated that the shipping industry incurs approximately EUR 253 million in costs as a result of ships diverting from their courses due to medical emergencies, and the total cost for the whole shipping industry is estimated to be around EUR 760 million [66]. The average cost of a ship diverting due to medical emergencies is EUR 2200 per hour [66].

In order to improve seafarers' health and reduce the economic and other consequences due to cardiac emergencies on board ships, modifiable risk factors should be managed. Our study is the first review reporting the pooled prevalence of modifiable risk factors, and highlighting the high prevalence of modifiable CVD risk factors among seafarers. It is also pointed out in this review that overweight and obesity are prevalent among seafarers, and this poses a safety hazard on board a ship. An overweight or obese seafarer may find it difficult to perform emergency operations such as using the emergency exits or climbing onto a rescue boat. Therefore, this review informs telemedical maritime assistance services (TMAS) physicians who provide teleconsultation services to seafarers by providing prevention advice or scheduled counseling on lifestyle changes in order to reduce modifiable risk factors, especially high body mass index. As a result, seafarers with high BMIs (25 kg/sqm and over) should be advised through telemedicine to engage in lifestyle measures, including exercise and dietary modification.

Furthermore, the results of our study alert telemedicine case managers or specially trained maritime officers who work with seafarers on board ships to monitor their blood pressure and blood glucose levels regularly. The working conditions of seafarers make monitoring regular blood pressure, blood glucose levels, and other lipid profile tests on board ships very challenging. However, thanks to telemedicine technologies, it is now possible to track seafarers' physiological parameters regularly and report the data to the TMAS doctors. Consequently, the TMAS doctors will contact the telemedicine case manager or the person responsible for healthcare services on board, or, if possible, they will contact the user directly. A real-time consultation via telemedicine is recommended for patients with elevated blood pressure or abnormal parameters.

Moreover, our study provides information to shipping companies to implement policies prohibiting smoking because smoking is not only a health problem but also a risky habit and a cause of fires on ships. The review findings, in general, urge shipping companies, and other responsible bodies, such as the IMO, MLC, and maritime health policymakers to focus on prevention programs in order to reduce modifiable CVD risk factors on board ships. We recommend that future studies take into account the causes of the modifiable risk factors on board ships.

5. Conclusions

The present study has demonstrated that seafarers have a high prevalence of CVD risk factors, particularly high blood pressure (45.32%), overweight (41.67%), smoking (40.14%), obesity (18.60%), and alcohol consumption (38.58%). This review found substantial heterogeneity between the included studies, although most of the included studies had a low risk of bias, which affected the certainty of the overall evidence. The present study also indicated that the pooled prevalence of overweight and obesity increased along with seafarers' age. The findings of this review will help the IMO, shipping companies, and other stakeholders to develop and implement telemedicine prevention strategies that address the common CVD risk factors considered in this study.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/jpm13050861/s1, Figure S1: A forest plot of the prevalence (%) of high blood pressure among seafarers after omitting the outlier studies; Figure S2: A forest plot of the prevalence (%) of overweight among seafarers after omitting the outlier studies; Figure S3: A forest plot of the prevalence (%) of obesity among seafarers after omitting the outlier studies; Figure S4: A forest plot of the prevalence (%) of diabetes mellitus among seafarers after omitting the outlier studies; Figure S5: A forest plot of the prevalence (%) of alcohol use among seafarers using a random effect model; Table S1: Literature Search strategies and results; Table S2: The Joanna Briggs Institute (JBI) Prevalence Critical Appraisal Tool; Table S3: Leave-one-out analysis for prevalence of smoking in seafarers; Table S4: Leave-one-out diagnostics with a built-in function in smoking prevalence among seafarers; Table S5: Leave-one-out analysis for prevalence of high blood pressure in seafarers; Table S6: Leave-one-out diagnostics with a built-in function in high blood pressure among seafarers; Table S7: Leave-one-out analysis for prevalence of overweight in seafarers; Table S8: Leave-one-out diagnostics with a built-in function in overweight prevalence among seafarers; Table S9: Leave-one-out analysis for prevalence of obesity in seafarers; Table S10: Leave-one-out diagnostics with a built-in function in obesity prevalence among seafarers; Table S11: Leave-one-out analysis for prevalence of diabetes mellitus in seafarers; Table S12: Leave-one-out diagnostics with a built-in function in diabetes mellitus prevalence among seafarers; Table S13: Leave-one-out analysis for prevalence of alcohol consumption in seafarers. Table S14: Leave-one-out diagnostics with a built-in function in alcohol consumption prevalence in seafarers.

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Review

The Use of Radio and Telemedicine by TMAS Centers in Provision of Medical Care to Seafarers: A Systematic Review

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Abstract: *Objective*: From medicine via radio to telemedicine, personalized medical care at sea has improved significantly over the years. Currently, very little research has been conducted on telemedicine services and tools at sea. This study aims to review real-time case studies of seafarers' personalized treatment via telemedical devices published in medical journals. *Methods*: A literature search was conducted using three libraries such as PubMed (Medline), Cumulative Index to Nursing and Allied Health Literature (CINAHL), BioMed Central, and Google Scholar. The Medical Subject Headings (MeSH) were used for information retrieval and document selection was conducted based on the guidelines of preferred reporting items for systematic reviews and meta-analyses (PRISMA) 2020 flowchart. Selected articles were subjected to quality checks using the Newcastle–Ottawa scale (NOS). *Results*: The literature search produced 785 papers and documents. The selection was conducted in three stages such as selection, screening, and inclusion. After applying predefined inclusion and exclusion criteria, only three articles on real-time medical assistance with telemedical tools were identified. It is reported that medical attention is delivered to seafarers in real time thanks to advancements in telemedicine, satellite technology, and video conferencing. *Conclusions*: By improving the quality of medical care and reducing response times for medical emergencies at sea, lives have been saved. There are still several gaps despite these advancements. Medical assistance at sea should therefore be improved to address many of the still unsolved issues.

Keywords: seafarers; TMAS; medical devices; maritime telemedicine; satellite technology; medical assistance at sea

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1. Introduction

The history of medical assistance at sea dates back to the early days of ocean exploration when mariners encountered various health hazards and medical emergencies with no possibility of being properly treated due to the lack of onboard health professionals. The development of radiotelegraphy by Guglielmo Marconi in 1897 has allowed us to provide medical assistance to ships from ashore medical centers or ships with medical facilities on board [1]. The realm of medical assistance at sea has evolved over the past century, largely owing to advancements in radio communication and, subsequently, telemedicine [2]. However, the medical assistance available to seafarers is often basic and limited to the use of elementary medical equipment, and non-advanced communication systems, such as, in the past, radio telegrams, and, currently, conventional e-mail or telephone calls.

With the development of radiotelegraphy and later radio telephony, medical professionals were able to transmit instructions and guidance to seafarers experiencing medical emergencies [3,4]. The use of internet-based communication systems, such as video conferencing, has enabled remote medical treatment to be provided to patients at sea more effectively and efficiently than ever before. These advancements in telecommunications have ensured swift and effective medical assistance along with the ability of providing medical services in the maritime environment. This approach has remarkably changed the provision of medical assistance at sea over time and has become relevant to ensure the safety and well-being of those on board.

Delivering medical assistance at sea poses several challenges and issues due to the unique environment and logistical constraints. Ships, especially those on long voyages or in remote areas, can be far from medical facilities or specialized care. This makes it difficult to access timely medical assistance in case of need. Having limited medical resources and specialized equipment can hinder the delivery of comprehensive medical care onboard. Also, limited or unreliable satellite connections can hinder real-time consultations with onshore medical professionals and delay diagnosis and treatment. In case of medical emergencies, timely evacuation to a shore-based medical facility may be necessary. However, arranging medical evacuations at sea can be logistically complex and expensive, especially in adverse weather conditions.

The use of telehealth on onboard ships helps deliver medical help minimizing the challenges and burdens encountered by seafarers. This is due to the limited medical knowledge of ship masters or onboard medical staff. Telehealth can also improve monitoring, timeliness, and communication within healthcare systems. Telemedical Maritime Assistance Service (TMAS) centers provide medical services based on radio codes through different channels such as email, marine radio, telephone, video conferences, and fax [5–7]. TMAS centers and seafarers began to use telehealth more frequently, especially, during the recent pandemic to reduce in-person contact [8,9]. The doctors at TMAS centers communicate over the phone, email, or video, which is beneficial for both patient health and practice [10,11]. Using digital medical devices, vitals are gathered, progress is monitored, external lesions can be viewed, and images of skin, ears, eyes, etc., can be captured and evaluated. The availability of digital devices like these has increased the effectiveness of telemedicine, overcoming the handicap of inaccurate information provided from the ship's side.

In the past few decades, telemedicine has further transformed the field, enabling the remote medical diagnosis and treatment of patients in maritime environments. A literature review of telemedical assistance in the marine industry domain has never explored the previous objectives in detail. Therefore, we will be able to provide a broader understanding of the area and facilitate future technological applications. Only two reports gave an overview of patient safety and legal impacts [12,13]. Another study gave an overview of European remote medical care services at sea from a variety of communication channels and generational perspectives [14].

As far as we know, no comprehensive study has focused on contextualizing data collection and medical operations between ships and TMAS centers using radio communications and telemedical devices. The purpose of this study was to explore the evolution of medical assistance at sea, from primitive radio-based methods to modern telemedicine. A discussion of existing medical assistance case studies has also been provided, along with the most important aspects, including techniques and communication tools.

2. Methodology

2.1. Document Search

The document search was conducted via different medical databases, such as PubMed (Medline), Cumulative Index to Nursing and Allied Health Literature (CINAHL), BioMed Central (BMC), and Google Scholar. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 guidelines were followed for document selection to promote transparency, completeness, and clarity in research reporting [15]. Medical Subject Headings (MeSH) terms are used for document indexing and retrieval. The search keywords 'telemedicine', 'seafarers', 'maritime industry', 'marine telehealth', 'seafarers health', 'radio medicine', 'remote telemonitoring', 'maritime telemedicine', and 'medical assistance at sea' were applied to identify real-time case studies where medical assistance at sea was carried out. Boolean operators like 'AND' and 'OR' were included in search databases to acquire variations in the vocabulary and for a better search strategy. Table 1 presents the document count retrieved from different databases.

Table 1. Document search count among different databases.

N	Databases	Document Count
1.	PubMed (Medline)	316
2.	CINAHL	8
3.	BMC	5
4.	Google Scholar	456

2.2. Inclusion Exclusion Criteria

Only documents published in the English language were considered. All the identified articles included a case study in which medical assistance at sea with tools or techniques was applied. The degree of analysis was not a significant inclusion criterion. Articles that did not include evidence of a case study with a clear motivation to protect seafarers from a medical point of view were included. Review articles and books were excluded from the study. Case studies on seafarers' blood sample data, onsite doctor visits, autopsy reports, and clinical pathways were excluded. Non-peer-reviewed, unpublished, conference proceedings, abstracts, and publications in languages other than English were also not considered.

2.3. Quality and Risk Bias Assessment

During the review process, each author independently screened papers and assessed their quality and relevance to the research. Papers were selected based on consensus among reviewers and conformity to inclusion and exclusion criteria. Upon reading the abstracts, the authors compiled a list of articles that they believed qualified in primer appraisal. Study quality was assessed using the Newcastle–Ottawa scale (NOS), which is a quality assessment tool that ranks studies and assesses the risk of bias [16]. It is fairly simple to interpret the NOS scale, which rates studies as poor (0–4), fair (5–6), and good (7–9). The studies that scored NOS ≥ 7 were considered for final review.

3. Results

The review findings and study characteristics, including interventions and outcomes, are presented in this section. We also summarize the key findings derived from the research across the studies in terms of providing medical assistance at sea.

3.1. Document Selection Flowchart

Figure 1 provides a PRISMA flow diagram for selected 785 articles among the given searched libraries. A careful review of the title and summary of each study revealed that 358 papers were ineligible; 139 were withdrawn because there were duplicates, and three did not have enough data. In total, 288 studies were screened based on the inclusion and exclusion criteria. Of these, 253 articles were excluded because they did not satisfy the exclusion and inclusion criteria (n = 94), they were reviews and books (n = 129), due to the unavailability of full text (n = 29), and because they were written in a language other than English (n= 1). Ultimately, 35 papers met the eligibility criteria for the review. Before reaching the final selection, the previously mentioned search words were examined for differences, and when one word was different from others of a similar kind, various thoughts were discussed. By considering NOS criteria, the authors gathered information helpful to the exploration effort by reading all the articles before choosing those that were qualified to be used for the study. Ultimately, nine studies were included in the final review because other studies did not provide the motivation behind the case study presentation, news synopsis, and meta-analysis.

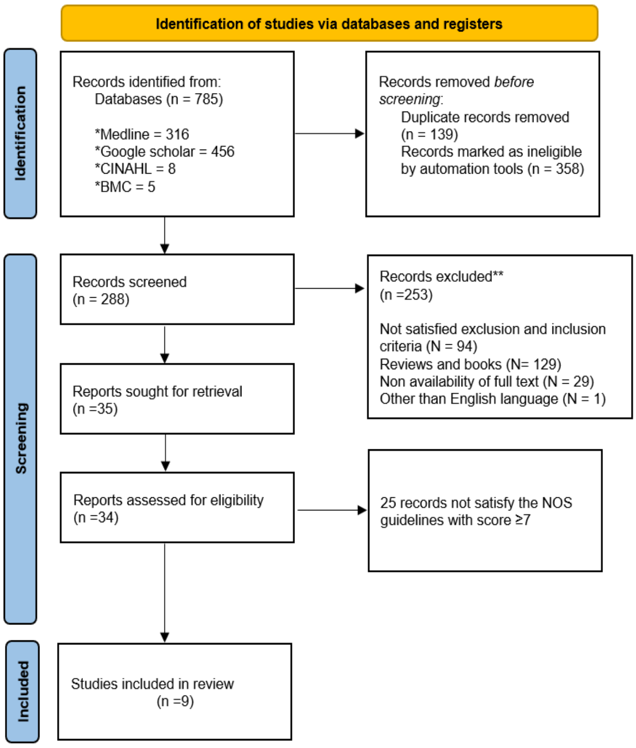

Figure 1. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases only (* searched database).

3.2. Communication Channels

By analyzing the studies that were finally selected, we identified that most seafarers contact TMAS centers for medical help through different means of communication. Figure 2 presents the frequency of work associated with distinct communication channels or telemedical technologies that were used by ships to contact onshore doctors. Five studies adopted the telephone [8,17–20], followed by email [8,18,19,21], radio [22,23], and web application platforms [24].

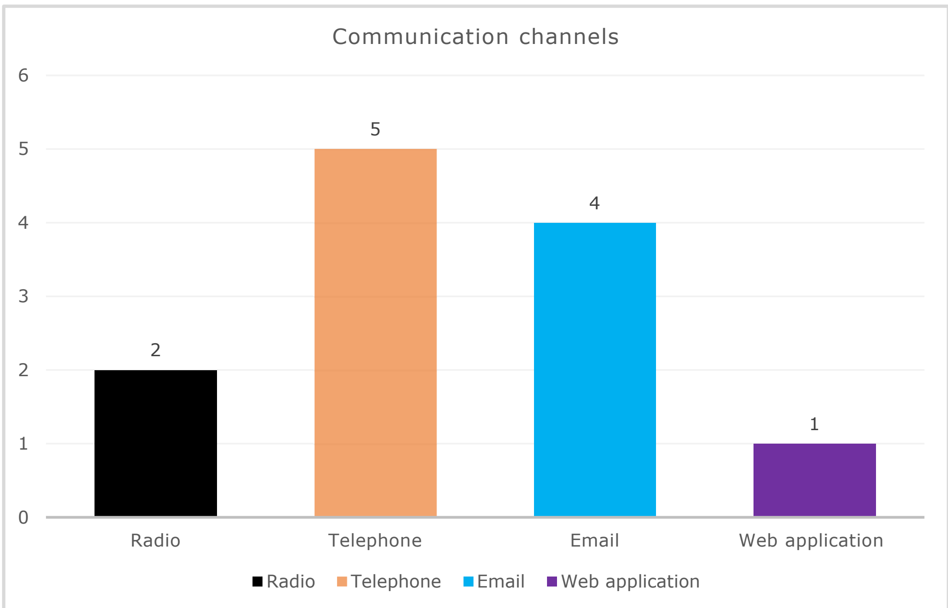

Figure 2. Different communication technologies are used for requests of medical assistance at sea.

3.3. TMAS Centers and Means Communication

Maritime emergencies, illnesses, accidents, and other incidents that require medical advice, based on the captain's decision, are managed by TMAS centers. Providing seafarers with health care is an essential part of their mission. TMAS centers in Europe conducted the majority of studies, while only one study was conducted in the US (Table 2). It appears that the Italian TMAS center, the International Radio Medical Center (C.I.R.M.), is one of the most populated in Europe. Additionally, seafarers contact these centers by telephone or by email to transfer their medical data, unlike RMD and CCMM, which use radios.

Table 2. List of TMAS centers associated with the present study.

TMAS Centre	Location and Country	Means of Communication
Med solutions international	New York, USA	Email
RMN	Bergen, Norway	Telephone
CCMM	Toulouse, France	Radiotelegraphy, Telephone
UCMTM	Gdynia, Poland	Telephone and Email
RMD	Esbjerg, Denmark	Radio
C.I.R.M.	Rome, Italy	Telephone, Email, and Web applications

RMN: Radio Medico Norway; CCMM: Centre De Consultation Medicale Maritime; UCTM: University Center of Maritime and Tropical Medicine; RMD: Radio Medical Denmark; and C.I.R.M: Centro Internazionale Radio Medico.

3.4. Study Characteristics

The major characteristics of examined studies based on study type, number of patients, year published, and observations are presented in Table 3. There was no evidence of studies reporting the telemedical assistance of seafarers with case studies before 2015. One study published in 1980 highlighted the transformation of medical messages from the casualty officer of the Royal Naval Hospital Plymouth via Portishead Radio [11]. This study analyzed the range of medicines prescribed for seafarers' medical problems. Several diseases have been linked to diet-associated factors, such as alcohol and obesity. Because the full free text was not available, it was not included in the final survey.

Table 3. Study characteristics.

Study Type	Sample	Year	Medical Advice	Observations	Ref
Descriptive	551	2016	Management of cardiac symptoms	Pre-employment medical examinations improved preventive measures.	[21]
Observational	169	2017	Emergency helicopter evacuations (helivacs) between the two ferries	Every two weeks, one person was airlifted. The majority of Halifax was heart-related, with more cardiac cases airlifted than ambulances	[17]
Case study	5	2017	Diagnoses and follows up on medical conditions were carried out	In the development of telemedical technologies, the participants demonstrate a continual interest in teleconsultations with photographs	[23]
Observational	225	2019	Ensure permanent access to medical advice for seafarers	Providing medical assistance for various medical problems to seafarers requires close multidisciplinary cooperation between medical officers.	[18]

Table 3. *Cont.*

Study Type	Sample	Year	Medical Advice	Observations	Ref
Retrospective cohort	1401	2019	Medical advice for injuries among seafarers	Danish-flagged merchant ships carry an increased risk of injuries to non-officers and European seafarers.	[22]
Retrospective	11,481	2020	Proposing prevention measures in COVID-19 Control	Fever, sore throats, and shortness of breath appeared to be more common during Coronavirus outbreaks	[8]
Epidemiological	423	2021	Assistance to control injuries and diseases among seafarers	Non-officers reported significantly more injuries and diseases than officers	[24]
Cross-sectional	420	2022	Diagnosis of marine workers' dermatological diseases	Highlighted insufficient remote management of dermatological conditions.	[19]
Observational	384	2022	Diagnosis of COVID-19	Promotes social distancing and quarantine procedures at sea to limit the spread of the pandemic	[20]

3.4.1. Medical Assistance via Radio

Radio was the first telecommunication system used to provide medical assistance at sea. It became an essential tool for ship captains in the early 20th century, allowing them to inform onshore centers and authorities about medical issues aboard their ships. During the literature search, two published works were found on radio medical assistance for seafarers. One study from the Denmark TMAS center (i.e., RMD) adopted radio-telephone communication to analyze the injury patterns of workers and the factors that contribute to injuries [22]. The system allowed ship captains to communicate with a medical doctor onshore and receive immediate medical advice over the radio. This allowed physicians to guide ship captains, who were responsible for providing emergency medical care to injured crews and passengers.

Five case studies presented by the French TMAS center (CCMM) illustrated the use of radiotelegraphy to diagnose and follow up on different medical conditions among seafarers living on ships [23]. To advance these practices, there is a need to develop video-conferencing technology. It is mentioned that radio calls enabled ships in the middle of the ocean to communicate effectively with medical personnel ashore, reducing the number of medical emergencies and deaths at sea.

3.4.2. Telemedicine Technologies

Seven studies are associated with the use of telemedicine, where medical professionals can now communicate with ships (via email, telephone, video conferencing, and web applications). This allows them to diagnose and treat medical conditions in real time [8,17–21,24]. Ships can contact TMAS by phone or by e-mail to provide a verbal description of a crew member's medical condition, followed by an email with images. There are, however, still several problems to be solved. In general, the doctor ashore does not talk directly with the patient or does not see him, as contact is mediated through the captain or the ship's officer with medical duties on board. This does not help to establish the fundamental patient-doctor relationship in the provision of medical assistance. On the other hand, the medical skills of the people with duties of medical assistance at sea are quite limited, and therefore this makes the delivery of medical assistance mediated by a third person complex. In an epidemiological study of seafarers' injuries, telemedicine was found to provide remote access to medical care for those suffering from health issues while at sea [24]. With telemedicine, physicians can provide medical consultations and treatment to individuals aboard ships or boats via secure remote connections. For instance, with telemedical devices (presented in Figure 3), medical information (or knowledge) can be shared between sailors and onshore doctors. Some studies have shown that physicians can examine and diagnose medical problems miles away from patients via telephone communications from a TMAS center [17,20]. Handling seafarers' medical records with email technology allows healthcare workers access to patient medical records, which helps determine appropriate treatment protocols [8,19,21]. In this way, seafarers obtain in-depth medical care regardless of where they are, and individuals at sea continue to benefit from telemedicine as technology advances.

Figure 3. On-board telemedicine case containing medical devices courtesy of TelePharmaTec, the spin-off of Camerino University, Italy.

Different contact possibilities are currently available for medical assistance at sea. The most popular is the store and forward method, which involves taking images or videos of a patient and transmitting them to a specialist for consultation [19,20,25]. Live telemedicine involves real-time audio-visual interaction between the provider and patient, similar to a video call. Remote patient monitoring involves collecting data from medical devices worn by patients and transmitting them to healthcare providers for analysis. This allows healthcare professionals to properly and continuously monitor patients' health status and intervene, if necessary. Mobile health (mHealth) uses mobile devices such as smartphones and tablets to remotely deliver healthcare services [26,27]. These include educational resources, appointment scheduling, and virtual doctor visits. As these studies do not align with the research objectives, they were therefore excluded from the final survey. Telemedicine is becoming an increasingly valuable tool for medical assistance at sea as technology advances.

Adopted works in this review have highlighted the implementation of ship-to-shore video conferencing, which has revolutionized the provision of medical assistance at sea [23,24]. Through this technology, medical officers onboard can communicate with onshore doctors in real time, allowing a more accurate diagnosis and treatment. Medical personnel on board can consult with experienced professionals onshore through video streaming and reliable communication channels. In this way, ships without qualified health professionals can still obtain high-level medical care and transfer at-risk patients to ashore medical facilities. Ship-to-shore video conferencing has greatly improved the lives of mariners, ensuring timely and effective medical treatment and reducing the risks associated with remote treatment.

4. Discussion

Medical assistance at sea has come a long way since its inception with radio-based medicine. The procedures used over the last century at TMAS centers for seafarers' healthcare are still in use today. Now onboard medical personnel can consult specialists onshore, share vital signs, and receive training via real-time audio and video communication. Our study explored the use of medical assistance via radio and telemedical devices during emergencies which have revolutionized the way patients at sea were treated. Medical professionals can guide crew members on board ships with limited medical equipment and resources [28,29].

Telemedicine has further enhanced the delivery of medical care at sea through real-time communication with onshore healthcare facilities [30]. Telemedical solutions provide remote access to healthcare professionals, electronic medical records, and consultations via satellite communications. Medical care at sea requires reliable medical care, which makes telemedicine increasingly important. The maritime industry relies on it to provide rapid medical assistance during emergencies, as well as ensure seafarers' safety.

TMAS centers provide remote healthcare services that allow maritime patients to receive medical care and advice from medical professionals located on land in real-time [30]. It ensures that medical advice and diagnosis can be received even on vessels far away from medical facilities. Using telemedicine, medical professionals on land can visit patients using images, vital signs, and video conferences and consequently prescribe treatments. The improvement of medical assistance provided by telemedicine has also been shown to reduce medical evacuations, prolong major interventions, and save lives [31]. The use of telemedicine has revolutionized the delivery of medical care to those at sea.

The advent of satellite technology has significantly expanded the geographic availability of medical assistance, enabling healthcare providers to reach remote and isolated destinations. As maritime activities continue to increase in a globalized world, medical assistance at sea has become increasingly indispensable. With the ongoing advancements in technology and the expanding role of telemedicine, it is poised to play an even greater role in the protection of seafarers' health in the future. With the continuous development of technology, healthcare providers can now rely on telemedicine to monitor patients' conditions and manage medical emergencies in real-time. Efforts should be carried out to provide seagoing vessels with appropriate telemedicine equipment and to guarantee that solutions provided by different producers work on the maritime environment and that their friendly use would allow the proper transmission of biomedical data ashore.

4.1. What Needs to Be Done?

Telemedicine systems have advanced to include high-resolution video conferencing capabilities, which make it possible for diagnosis, treatment, and consultation to be conducted remotely [32,33]. By using these technologies, onshore medical practitioners can provide direction and guidance to onboard medical officers. Telemedicine ensures that crew members and passengers have access to qualified health care with accurate medical advice and support [34,35]. Additionally, it reduces unnecessary rescue operations and costs. Hence, telemedicine is an efficient, cost-effective, and beneficial method to deliver medical assistance to ships.

4.1.1. Integration of Artificial Intelligence (AI) in Telemedicine

The integration of artificial intelligence (AI) has provided telemedicine with the ability to offer a more personalized approach to diagnosis and treatment. The establishment of AI-based telemedicine systems for maritime vessels has numerous benefits. An AI-based marine doctor system enables prompt and efficient medical assistance to seafarers and crew members who encounter health complications [25]. Physicians can make informed decisions based on AI algorithms that analyze patient histories, laboratory results, and imaging studies [36]. Medical professionals will be able to make more accurate diagnoses, provide better treatment plans, and improve patient outcomes. It is important to address concerns regarding data privacy and ethical considerations regarding AI in telemedicine. AI has the potential to revolutionize telemedicine and enable healthcare providers to reach remote and underserved populations with high-quality medical care.

4.1.2. Satellite Telecommunications

Medical assistance at sea has been remarkably improved by satellite communication. Communication channels can be established between vessels and land-based medical professionals, allowing for real-time consultations, diagnosis, and intervention on-site [37,38]. Satellite networks can transmit large amounts of data, including high-definition images and videos, which are essential for accurate diagnosis and medical support [39]. Satellite connections also allow remote monitoring of vital signs and other health parameters, making it possible for medical professionals to track the health status of patients in real-time.

Telemedicine consultations in case of medical issues on board are becoming increasingly popular for providing health care at sea. Using this approach, doctors can provide advice and guidance to seafarers from their locations using video conferencing. This method of healthcare delivery is especially helpful for remote vessels that lack onboard medical facilities and personnel [40]. In emergencies, telemedicine consultations can help diagnose and treat illnesses and injuries in real-time, reducing the need for medical evacuation. As technology continues to improve, telemedicine will become more accessible and affordable for mariners, providing them with much-needed medical assistance at sea. Despite these benefits, there are still challenges to overcome, such as connectivity issues and regulatory hurdles. There is also a need for greater diffusion of telemedical devices on ships and specific training of ship medical officers in telemedicine.

4.2. Implications of Medical Assistance at Sea in Healthcare

The implications of medical assistance at sea are numerous and far-reaching in the field of healthcare. The ability to provide medical care remotely, particularly in critical situations where time is essential has proven to be lifesaving in many instances [37,41–43]. The advancement of technology has enabled healthcare professionals to virtually reach patients in remote areas, improving diagnosis, treatment, and outcomes. The use of telemedicine can also reduce healthcare costs by avoiding expensive and potentially risky emergency medical evacuations. Additionally, telemedicine can improve access to health care in underserved areas. Healthcare providers and policymakers will need to address questions of efficacy and ethics as remote medical services expand.

4.3. Regional Context and Digital Divide Issues

Telemedicine is a rapidly growing field that has the potential to revolutionize healthcare delivery, especially in remote and underserved regions. It is important to consider the regional context and digital divide issues when considering telemedicine for sailing seafarers.

The availability and accessibility of telemedicine services can vary significantly across different regions. Seafarers may already be able to access telemedicine services in coastal areas or regions with a strong maritime industry, such as major port cities [44]. A dedicated telemedicine center or clinic should be properly equipped to provide remote consultations, diagnoses, and even certain treatments to seafarers at sea in such regions. On the other hand, in less developed or remote coastal regions, the availability of telemedicine services may be limited. Telemedicine may not be feasible in areas lacking reliable internet connectivity or advanced medical equipment [45]. Telemedicine for seafarers would require significant infrastructure development and capacity building.

The digital divide refers to the gap in access to and utilization of digital technologies between different populations or regions [46]. Seafarers who work on vessels operating in international waters or regions with limited connectivity may face difficulties in accessing telemedicine services due to unreliable or nonexistent internet connections [47]. The digital divide requires collaborative efforts from the government, maritime industry bodies, and telecommunications companies. By improving internet infrastructure and providing training programs for seafarers, telemedicine services can be made more accessible to all. Consequently, while telemedicine can provide valuable medical care to sailing seafarers, regional context and digital divide issues need to be considered. By addressing disparities in internet access and telemedicine infrastructure in a particular region, seafarers can access effective healthcare.

4.4. Limitations

This study typically focuses on specific research questions or interventions. As such, there is a chance it is not addressing all relevant aspects of the topic, potentially overlooking important outcomes, subgroups, or alternative interventions. Due to a limited number of studies the applicability and review findings with a special group of population, settings, or contexts may be limited. Because the included studies have focused on seafarers, it makes it challenging to generalize the findings to broader populations or different healthcare systems. Despite these limitations, we are confident that this study could contribute to the synthesis of evidence and provide an overview of the available literature.

5. Conclusions

In modern medical care at sea, telemedical assistance is an essential component, allowing for quick and accurate diagnosis, timely treatment, and improved patient outcomes. Although medical assistance at sea has been available for more than 100 years, little research has been carried out on its evaluation. In this study, we examined telemedicine's role in maritime healthcare and examined how it has evolved. Throughout this review, we discussed technological advancements in medical assistance at sea. Since radio medical assistance was introduced in the past, telemedicine has improved the quality of healthcare for seafarers worldwide.

Despite its current limitations, telemedicine is set to continue improving medical assistance onboard ships in the future. More accurate remote diagnosis and treatment may be possible for doctors and other health professionals with advanced technology. Sophisticated monitoring systems and medical equipment can contribute to achieving this goal. As a result of AI, accurate predictions of illnesses and identification of high-risk patients could be achieved with significant benefits. Research and development investment by government agencies is crucial for improving healthcare service delivery.

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