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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:

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

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)−0.20 x Engine (E)−0.66 x Galley (G)+0.58× Work experiences (W)+0.02 × Working hours per week (Wr)+1.69× Smoking (S)+0.78× Alcohol consumption (Al)+1.28× Snoring (Sn)+0.11× BMI

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

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

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

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

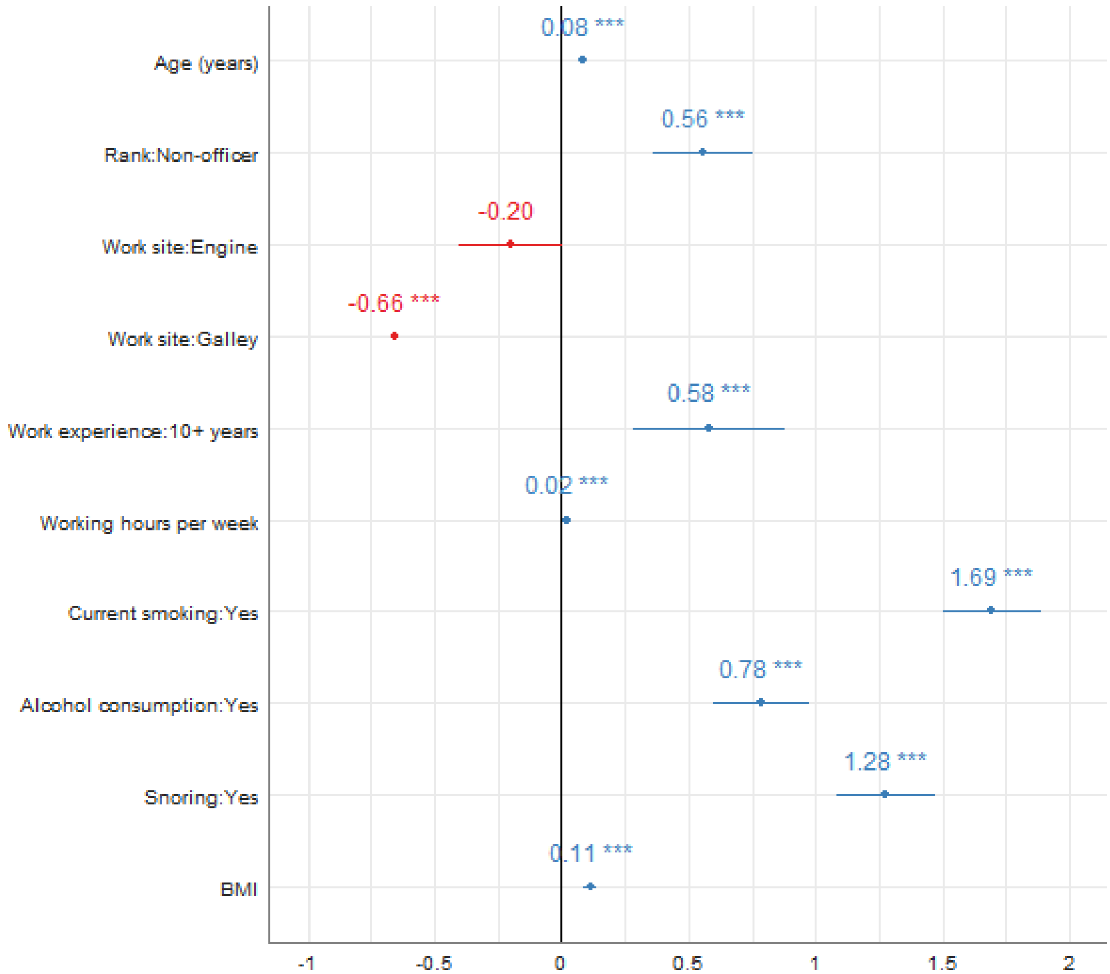

Figure 1 Forest plot of regression coefficients and their 95% CI for multiple logistic regression analysis of self-reported hypertension among seafarers. ***p<0.001. BMI, body mass index.

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

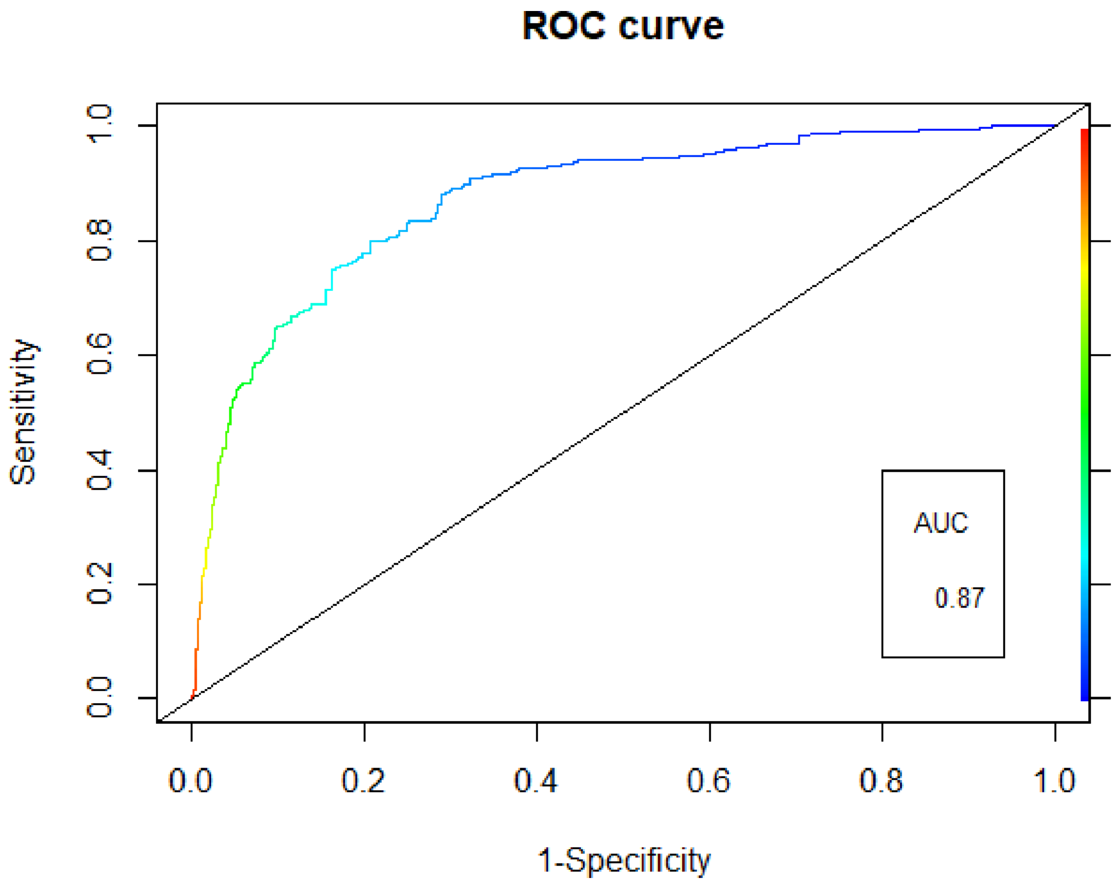

Figure 2 Receiver operating characteristic (ROC) curve of final a risk prediction model for seafarers with self-reported hypertension.

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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