Association Between the ''COVID-19 Occupational Vulnerability Index'' and COVID-19 Severity and Sequelae Among Hospital Employees

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Objectives: In addition to personal and health related factors, healthcare workers have an increased risk due to their work. We assessed the association of the score of the Occupational Vulnerability Index with the risk of suffering a severe COVID-19 and sequelae. **Methods:** Retrospective observational study carried out in healthcare workers. Among 119 employees infected, the COVID-19 Occupational Vulnerability Index (composed of 29 items regarding personal health, working conditions, and ability to comply with preventive measures) was calculated and correlated with COVID-19 severity/sequelae. **Results:** Workers with higher scores (six to seven points) had a significantly increased risk of developing severe disease (OR = 9.73; 95% CI, 1.53 to 35.56) and clinical sequelae (OR = 5.22; 95% CI, 1.80 to 15.16) than those with lower scores (0 to 3). **Conclusion:** The **"**COVID-19 Occupational Vulnerability Index**"** may predict the risk of severe COVID-19 disease and clinical sequelae among healthcare workers.

Keywords: COVID-19 occupational vulnerability index, COVID-19 sequelae, COVID-19 severity, healthcare workers

In December 2019, a new highly contagious coronavirus was reported: SARS-Cov-2 (Severe Acute Respiratory Syndrome Coronavirus 2) and first described in Wuhan, China.[1] A global pandemic was declared on March 11, 2020 according to the World Health Organization.[2] The coronavirus Disease 2019 (COVID-19) has had an impact throughout society, but especially in the health care sector. Hospitals became a focus of the COVID-19 pandemic,[3] especially in countries such as Spain and Italy where more than 20% of these countries' total infections occurred among health professionals.[4,5] This was particularly true in the first wave of infection during March, April, and May 2020. During this initial phase of the pandemic, a considerable number of infected healthcare workers developed complications.[6]

Personal variables like age and comorbidities are known to influence the vulnerability of people to COVID-19 and are associated with the severity of the infection and its case-lethality.[7,8] The working conditions of healthcare personnel such as avoiding unprotected exposure to aerosols or droplet-generating procedures and their ability to comply with other appropriate prevention measures have been shown to be important in lowering infection rates among hospital personnel.[9] Greater severity of infection due to high viral loads has also been described.[10] These clinical aspects also influence the likelihood of developing subsequent sequelae.[11,12]

Therefore, we used a questionnaire that takes into consideration three dimensions that are known or strongly suspected to have impacts on the degree of COVID-19 severity: personal health risk factors, work exposures/conditions, and the ability to comply with preventive measures.

The aim of the questionnaire is to predict a healthcare workers' vulnerability to COVID-19 infection complications based on their numeric score or COVID-19 ''Occupational Vulnerability Index'' (OVI),[13,14] and this study retrospectively evaluated the association between the OVI score and the risk of suffering severe COVID-19 disease/sequelae among the staff of a hospital in northern Spain, during the first wave of the COVID-19 pandemic.

METHODS

Study Design and Participants

Inside the SECOCO study (assessment of seroconversion prevalence among healthcare professionals involved with COVID-19 diagnosed patients), a retrospective observational study was carried out in healthcare workers from the University of Navarra Clinic (CUN), a hospital in the north of Spain. The information was obtained during the months of September and October 2020 through telephone interviews, in which the participants were asked about the items of the COVID-19 Occupational Vulnerability Index. Other variables which showed the severity of the infection were independently collected from the healthcare workers' medical records.

All CUN staff who had suffered COVID-19 disease were included in the study. All infections were confirmed by Real-Time polymerase chain reaction (PCR) test among staff with symptoms compatible with COVID-19 during the months of March to May. In addition, during the month of June, a serological screening for COVID-19 specific antibodies was carried out on all the Clinic's staff. Using the seroprevalence results, we also included infected healthcare workers who were asymptomatic, had atypical and/or unreported symptoms.

The study was conducted according to the Declaration of Helsinki, and the institutional review board of the University of

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Clinical Significance: A vulnerability score, including data on personal previous health, working place and conditions, and the ability to comply with preventive measures has been shown to predict the risk of severe Covid-19 and its sequelae in healthcare workers. This score can be used to detect healthcare professionals at higher risk position.

Authors' contributions: X.N.F., S.K., M.T.V., and A.F.M. formulated the study question and research design. X.N.F. and A.F.M. acquired data, performed data analyses and drafted the manuscript. All authors contributed to the interpretation of data, critical revision of the manuscript, and approved the final version.

Conflicts of Interest: S.N.K. has received COVID-19-related consulting fees from Open Health. All other authors declare no competing interests. None of the authors received funding toward the present study.

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Navarra approved all procedures involving human subjects. This study was approved by the Research Ethics Committee of the Universidad de Navarra. The registration number for this study is 2020.67. Patients are agreed in research and dissemination plans of the research.

Exposure Assessment: OVI Score

The OVI score was developed and published by the AEEMT (Asociación Española de Especialistas de Medicina del Trabajo) working group as a Proposed Protocol for Risk Assessment and Stratification.[13,14] This questionnaire tool focuses on three areas: personal health risk factors, work exposures/conditions, and the ability to comply with preventive measures (Table 1).

The work exposures/conditions questions relate to the aspects of the hospital workers and the safety of their jobs, including compliance or non-compliance with protection measures and the contact with potentially contaminated aerosols are evaluated in the tool. Aerosol-generating processes, especially when they involve patients with severe disease are thought to be an important risk factor for infection severity among healthcare personnel.[10,30]

The scoring of the questionnaire (COVID-19 Occupational Vulnerability Index) is shown in Table 1.

Outcome Assessment: Severity of the Disease and Chronic Disease Sequelae

As indicators of disease severity, we considered severe disease as COVID-19 requiring hospitalization and/or resulting in bilateral pneumonia as diagnosed by CT-Scan.

We considered chronic disease sequelae as symptoms that hospital staff were still suffering when they were interviewed, 4 to 6 months later.

The outcome variables were defined in dichotomously: mild COVID-19 infection (those people with positive Real-Time PCR or positive antibodies in the serological test who did not present bilateral pneumonia and were not hospitalized) and severe COVID-19 infection (those who after positive Real-Time PCR were diagnosed with bilateral pneumonia or were hospitalized because of the infection). Likewise, sequelae were present or absent.

Statistical Analyses

According to the OVI score, participants were divided into terciles of low, medium, and high scores. The distribution of the categories was in terciles: tercile one (score between zero and three points), tercile two (four to five points), and tercile three (six to seven points). Logistic regression models were fit to assess the risk of severity in the COVID-19 disease and risk of suffering sequelae according to the score terciles of the questionnaire. Odds ratios (ORs) and their 95% confidence intervals (95% CIs) were calculated considering the lowest category: tercile one as the reference category.

We also used a logistic regression model considering the score of the questionnaire as a continuous variable to analyze the increase risk of severity and of suffering sequelae for each one-point score increase. Linear trend tests were calculated by assigning the median score of each category to all participants in that category and treating this variable as a continuous variable. For all the analyses we fitted a crude model and a sex adjusted model. However, we did not adjust for age, because age was a factor in determining the OVI score.

To evaluate the difference between the average scores of the questionnaire according to the presence or absence of severe COVID-19 disease or sequelae, a student *t* test was studied showing the averages and standard deviations. All *P* values presented are two-tailed; $P < 0.05$ was considered statistically significant. Analyses were performed using STATA/SE version 12. 0.

TABLE 1. COVID-19 Occupational Vulnerability Index

Individual Risk Factors Related to COVID-19 Vulnerability[7,15,16].	**Score**
Age	
<60 years	0
60–65 years	1
≥65 years	2
Sex	
Man	0
Non-pregnant woman	0
Pregnant woman	1
Total score of Individual risk factors.	
Previous Comorbidity and its Control Related to COVID-19 Vulnerability[17]	**Score**
Diabetes[18]	
Not applicable	0
Compensated/Controlled	1
Uncompensated/Uncontrolled	2
Hypertension[19]	
Not applicable	0
Compensated/Controlled	1
Uncompensated/Uncontrolled	2
Obesity[20]	
BMI <30	0
BMI 30–40	1
BMI >40	2
Cardiovascular disease[21]	
Not applicable	0
Compensated/Controlled	1
Uncompensated/Uncontrolled	2
Tobacco use[22]	
No	0
Yes	1
Disease with impaired coagulation[23]	
Not applicable	0
Compensated/Controlled	1
Uncompensated/Uncontrolled	2
Chronic lung disease[24]	
Not applicable	0
Compensated/Controlled	1
Uncompensated/Uncontrolled	2
Chronic liver disease[25]	
Not applicable	0
Compensated/Controlled	1
Uncompensated/Uncontrolled	2
Immunosuppressed disease[26]	
Not applicable	0
Compensated/Controlled	1
Uncompensated/Uncontrolled	2
Rheumatic/autoimmune disease[27]	
Not applicable	0
Compensated/Controlled	1
Uncompensated/Uncontrolled	2
Chronic inflammatory bowel disease	
Not applicable	0
Compensated/Controlled	1
Uncompensated/Uncontrolled	2
Cancer[28]	
Not applicable	0
Without treatment or sequalae from <1 year	1
With treatment up to <1 year	2
With current treatment or sequalae	3
Major surgery[29]	
Not applicable	0
Without treatment or sequalae from <1 year	1
With treatment up to <1 year	2
With current treatment or sequalae	3
Total score of previous comorbidities	

Occupational Risks Related to COVID-19 Vulnerability	Score
Health sector	
No aerosol-generating procedures and strict compliance with preventive measures	1
No aerosol-generating procedures, but with partial or total failure to comply with preventive measures	2
Carrying out of aerosol generating procedures with strict compliance with preventive measures	3
Carrying out of aerosol generating procedures with non-compliance of preventive measures	4
Social health workers. Including workers of nursing homes and social services	
With rigorous compliance with preventive measures	1
With partial or total breach of preventive measures	2
State security forces and firefighters	
With rigorous compliance with preventive measures	1
With partial or total breach of preventive measures	2
Cleaning or maintenance personnel working in areas with patients COVID-19	
With rigorous compliance with preventive measures	1
With partial or total breach of preventive measures	2
Social services personnel serving the community or dependent persons	
With rigorous compliance with preventive measures	1
With partial or total breach of preventive measures	2
Personnel with habitual relationship with possible cases (continuous attention to the public)	
With rigorous compliance with preventive measures	1
With partial or total breach of preventive measures	2
Staff with sporadic relationship with possible cases (non-continuous/sporadic attention to the public)	
With rigorous compliance with preventive measures	1
With partial or total breach of preventive measures	2
Personnel unrelated to possible cases (isolated or individual work)	
No need for specific preventive measures (hygienic)	0
Total score of Occupational risks	

Preventive Management at the Workplace Related to COVID-19 Vulnerability.	Score
Availability of barrier element-PPE	
Total availability	0
No availability or partial availability	1
Preventive training	
Regular and certified specific training and information	0
Irregular and/or non-protocol specific training and information	1
Health surveillance	
Specific regular and protocolized health surveillance	0
Specific surveillance of irregular and/or non-protocolized health	1
Option to modify the conditions of the position and/or job change options if necessary	
Possible or not necessary	0
Not possible or incomplete	1
Total score preventive management at the workplace	

RESULTS

The working population at the time of the study was 2179 employees of which 129 (5.92%) were diagnosed with COVID-19. Of the 129 positives, 10 did not answer the questionnaire (92.25% participation). Out of a total of 119 participants, the average age of the population is 40.6 (SD: 11.6) and 21.7% are men. In tercile one, 4.2% people suffered a severe COVID-19 and 34.04% suffered sequelae. In the second one, 24.4% people suffered severe COVID-19 and 53.3% suffered sequelae. In tercile three, 29.6% people suffered severe COVID-19 and 70.3% suffered sequelae.

We considered chronic disease sequelae as symptoms that hospital staff were still suffering when they were interviewed, 4 to 6 months later. These were reported in 59 (49.5%) healthcare workers in total. Most were mild sequelae: 16 had alopecia, 17 loss or decrease of sense of smell and taste, 8 joint pains, and 21 asthenia. Ten people had neurological sequelae such as headaches, dizziness, migraines, memory loss, insomnia, or nightmares and nine people suffered cardiological sequelae, one person with pericarditis, and eight with tachycardia. In addition, several patients reported generalized pain, changes in intestinal transit, dermatological alterations, one person gastritis, another with anemia, and a pregnant woman with hyperemesis gravidarum.

The background characteristics of participants according to the OVI score are shown in Table 2. Compared with subjects with low scores (zero to three points), those who had high scores (six to seven points) reported worse working conditions, less access to personal protective equipment (PPE), and receiving less preventive training. There were no differences in age and sex. The hospital's population was largely healthy at baseline and practically without personal health risk factors, only the tobacco/nicotine use was reported more frequently among upper two terciles ($P = 0.038$).

Those workers with the higher OVI scores (six to seven points) had a significantly increased risk of developing severe disease (OR = 9.73; 95% CI, 1.53 to 35.56) compared with those with lower OVI scores (0 to 3), after adjusting for sex (Table 3). Workers with high OVI scores also had a significantly increased risk of developing chronic sequelae of the disease (OR = 5.22; 95% CI, 1.80 to 15.16) compared with those in the lowest tercile OVI score (0 to 3), after adjusting for sex (Table 4). Examining the OVI score as continuous variable, we found that the risk of suffering severe disease was 2.63 (95% CI, 1.36 to 5.08)-fold higher for each point increment, adjusted for sex (Table 3) and the risk of suffering sequelae was 2.29-fold (95%CI, 1.36–3.86) higher for each point increment, adjusted for sex (Table 4).

The average of the COVID-19 OVI score was higher in the groups of the severe COVID-19 disease and the group that suffers sequelae because of the COVID-19 disease. The group with severe disease scores in average 1.25 points more than the group with a mild disease or asymptomatic; these differences were statistically significant $P = 0.006$. Also, the group that suffers sequelae because of the disease scores in average 1.1 points more than the group without sequelae; these differences were statistically significant $P = 0.001$ (Fig. 1).

DISCUSSION

In this retrospective study of healthcare workers and hospital staff we found that people with a high COVID-19 Occupational Vulnerability Index (6 to 7) showed an increase of their risk of severe COVID-19 disease OR = 9.73; 95% CI: (1.53 to 35.56), and of their risk of suffering sequelae OR = 5.22; 95% CI (1.80 to 15.16).

Our study population is mainly a young and healthy population. Also, the workers who had pre-existing pathologies were probably conscious of their own vulnerability to the virus and because of this they have sought lower exposure roles and took greater precautions so as not to be infected by the virus. Although it is a young and healthy population, almost 18% suffered severe COVID-19 illness and 50% reported some type of sequelae and the aging of the health care workers are increasing in the last years.[31] Therefore, it is important to identify criteria of vulnerability other than personal conditions and individual previous comorbidities.

The novel results found in this study were that personal vulnerability to the virus due to previous health and personal conditions are not the only risk factors for severe illness or for suffering sequelae (which has been shown in many studies)[8,17]; working conditions and compliance with preventive measures are

TABLE 2. Baseline Characteristics of Participants According to COVID-19 Occupational Vulnerability Index

Questionnaire Tool Score	Tercile 1 (0–3)	Tercile 2 (4–5)	Tercile 3 (6–7)	*P* Value
Participants, *N*	47	45	27	
Sex, women *N*, (%)	38 (80.85)	36 (80)	21 (77.78)	0.957
Age	39.7 (±11.6)	41.5 (±11.2)	40.8 (±12.6)	0.768
Pregnancy *N*, (%)	0	1 (2.22)	1 (3.70)	0.518
Diabetes disease *N*, (%)	0	0	0	..
Hypertension *N*, (%)	0	2 (4.44)	0	0.191
Obesity (BMI >30) *N*, (%)	0	3 (6.67)	2 (7.41)	0.133
Tobacco/nicotine use *N*, (%)	1 (2.13)	5 (11.11)	5 (18.52)	0.038
Cardiovascular disease *N*, (%)	0	0	0	..
Coagulopathy disease *N*, (%)	0	0	0	..
Chronic lung disease *N*, (%)	0	0	0	..
Chronic liver disease *N*, (%)	0	0	1 (3.70)	0.227
Immunosuppression disease *N*, (%)	0	0	1 (3.70)	0.227
Rheumatic disease *N*, (%)	1 (2.13)	1 (2.22)	4 (14.81)	0.038
Inflammatory bowel disease *N*, (%)	0	1 (2.22)	0	0.605
Cancer last year *N*, (%)	0	2 (4.44)	0	0.191
Major surgery last year *N*, (%)	1 (2.13)	0	0	1
Health worker conditions:				<0.001
Health worker conditions 1* *N*, (%)	17 (51.52)	1 (2.63)	0	
Health worker conditions 2† *N*, (%)	8 (24.24)	14 (36.84)	1 (3.7)	
Health Worker conditions 3‡ *N*, (%)	8 (24.24)	5 (13.16)	0	
Health worker conditions 4§ *N*, (%)	0	18 (47.37)	26 (96.38)	
Cleaner, without appropriate conditions *N*, (%)	1 (50)	1 (100)	0	1
Personnel in habitual relation with possible patients, without appropriate conditions *N*, (%)	1 (25)	5 (100)	0	0.048
Personnel in sporadic relation with possible patients, without appropriate conditions *N*, (%)	0	0	0	..
Personnel unrelated with possible patients *N*, (%)	3 (100)	0	0	1
No access to PPE *N*, (%)	5 (10.64)	27 (60)	27 (100)	0.001
No preventive training *N*, (%)	7 (14.89)	22 (48.89)	23 (85.19)	0.001
Without health surveillance *N*, (%)	0	0	0	..
Without option to modify the conditions of the position and/or job change options if necessary *N*, (%)	0	0	0	..
Profession				0.06
Doctor *N*, (%)	10 (21.28)	9 (20)	3 (11.11)	
Nurse *N*, (%)	19 (40.43)	20 (44.44)	14 (51.85)	
Assistant *N*, (%)	4 (8.51)	6 (13.13)	7 (25.93)	
Hospital porter *N*, (%)	2 (4.26)	3 (6.67)	3 (11.11)	
Other professionals *N*, (%)	12 (25.53)	7 (15.56)	0	
PCR positive *N*, (%)	35 (74.47)	34 (75.56)	25 (92.59)	0.134
IgG positive *N*, (%)	43 (91.49)	42 (95.45)	27 (100)	0.324
IgM positive *N*, (%)	23 (58.9)	25 (69.44)	17 (73.91)	0.541

*Health worker without contact with aerosols and rigorous use of the preventive measures.
†Health worker without contact with aerosols but without rigorous use of the preventive measures.
‡Health worker in contact with aerosols and rigorous use of the preventive measures.
§Health worker in contact with aerosols and without rigorous use of the preventive measures.

also important. If we split the questionnaire into three dimensions (personal health risk factors, work exposures/conditions, and the ability to comply with preventive measures), using only personal health risk factors we did not find a significant difference in the score of people with severe infections or sequelae and the people with mild infection and without sequelae (Fig. 1). This is probably because the scores on these questions in our population were very low due to the good baseline health of our population. Almost all the total OVI score in our population resulted from work exposures/conditions, and the ability to comply with preventive measures.

TABLE 3. Risk of Severity According to COVID-19 Occupational Vulnerability Index

Questionnaire Tool Score	Tercile 1 (0–3)	Tercile 2 (4–5)	Tercile 3 (6–7)	For Each Point Increment	*P* for Trend
Participants, *N*	47	45	27		
Incidence	2	11	8		
Crude OR (95% CI)	1 (ref)	7.28 (1.51–35.03)	9.47 (1.84–48.82)	2.59 (1.34–4.98)	0.004
OR adjusted for sex (95% CI)	1 (ref)	7.37 (1.53–35.56)	9.73 (1.53–35.56)	2.63 (1.36–5.08)	0.004

TABLE 4. Risk of Suffer Sequelae According to COVID-19 Occupational Vulnerability Index

Questionnaire Tool Score	Tercile 1 (0–3)	Tercile 2 (4–5)	Tercile 3 (6–7)	For Each Point Increment	*P* for Trend
Participants, *N*	47	45	27		
Incidence	16	24	19		
Crude OR (95% CI)	1 (ref)	2.21 (0.96–5.13)	4.60 (1.65–12.80)	2.15 (1.30–3.56)	0.003
OR adjusted for sex (95% CI)	1 (ref)	2.32 (0.98–5.51)	5.22 (1.80–15.16)	2.29 (1.36–3.86)	0.002

It would be recommended to increase the sensitivity of the OVI for a working population, by changing the age cuts more accordingly to a worker population. Knowing that a higher risk of severe COVID-19 disease has been observed for persons over 50 years old,[7] in the individual risk factor we should put the age cuts in 50, 55, and 60 years old. If we applicate these new cut-offs, to our study, we obtain an OR of severe COVID-19 disease in the third tercile of 10.32 (95% CI 2.03 to 52.35).

One of the most important contagion routes of SARS-Cov-2 is by airborne transmission, specially by aerosol generating procedures. The high infectivity of aerosols and the risk of severe illness due to this contact is mediated by the increased severity of infection experienced by people exposed to high viral loads. This increased viral load in the infection can be related to people who have been in contact with high viral load environments like aerosols.[10,29] Previous training and access to PPE materials have also been demonstrated to be essential infection control measures.

Based on this evidence, and to what was observed in the study we now know that the place of highest risk of suffering a serious illness was not the front lines of dealing with the virus, because, in emergency rooms, ICUs, and other places where the presence of COVID-19 was known, more preventive measures against the infection were taken, healthier healthcare workers were assigned, and greater care of the personnel was taken. In contrast, in areas where the virus was not known to be present, the healthcare workers population didn't received the training, the protective equipment or the appropriate care needed. In this situation, aerosols and nebulization treatments of incorrectly thought not to be infected patients led to high viral loads in environments where staff were not adequately prepared. This is where exposure to the virus became most risky for severe illness or long-term sequelae.

According to the retrospective methodology of our study, recall bias is the main limitation, where persons more severely affected are more likely to recall adverse exposure conditions. Additionally, with respect to long-term sequelae these were self-reported and no independent verification of relatedness to COVID-19 was performed.

Our sample of 129 is small. It is likely that because of this, there are dimensions in the COVID-19 Occupational Vulnerability Index that are not significant in predicting the risk of disease severity or sequelae, such as those related to personal health risk factors. But the total result adding up all the dimensions has shown a strong statistical association.

This study is of interest because it shows that previous health and personal conditions are not the only risk factors for severe illness or sequelae (which has been shown in many studies); working conditions and rigorous compliance of preventive measures are also important. This is essential when considering a young and

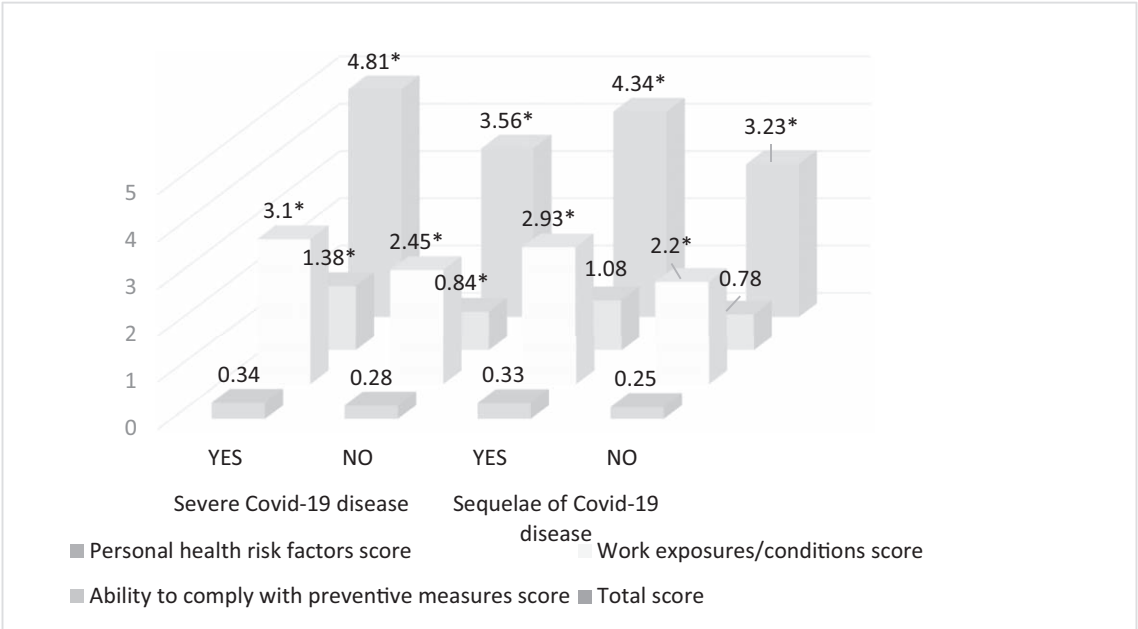

FIGURE 1. Average COVID-19 Occupational Vulnerability Index and its different areas according to the presence of severe COVID-19 disease or COVID-19 sequelae. *Statistically significant differences ($P < 0.05$).

healthy population such as hospital workers because they should be considered as a population at risk due to their work situation.

The application of our study is based on the usefulness of the tool ''COVID-19 Occupational Vulnerability Index'' to predict the risk of severity of COVID-19 disease and/or the risk of suffering long-term sequelae. We have found an association between high scores on the questionnaire and the risk of suffering a serious disease or sequelae. The association found is a direct prediction: the higher score, the greater risk. This tool is of special interest to indicate which population is more vulnerable in a young population without risk criteria associated a priori. In a population where there is no vulnerability because of previous health situation, such as in a hospital, the tool allows us to indicate which sectors of health workers will be in worse conditions in view of the vulnerability generated by their health care and their working conditions at the same level of previous health status and therefore it can help us know which population should be provided with appropriate training and better PPE. Also, as for the distribution of vaccines the COVID-19 Occupational Vulnerability Index and subsequent analysis of the positions most at risk can help organize the priority of vaccine distribution in the hospital environment.

In conclusion, while future prospective studies should be done with larger, multicenter population samples, the ''COVID-19 Occupational Vulnerability Index'' may be a useful tool to discriminate the risk of severe COVID-19 disease and COVID-19 sequelae among workers in a healthcare environment.

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