



Article

# Acceptance of COVID-19 Vaccine Booster Doses Using the Health Belief Model: A Cross-Sectional Study in Low-Middle- and High-Income Countries of the East Mediterranean Region

Ramy Mohamed Ghazy <sup>1,\*</sup>, Marwa Shawky Abdou <sup>2</sup>, Salah Awaidy <sup>3</sup>, Malik Sallam <sup>4,5,6</sup>, Iffat Elbarazi <sup>7</sup>, Naglaa Youssef <sup>8</sup>, Osman Abubakar Fiidow <sup>9</sup>, Slimane Mehdad <sup>10</sup>, Mohamed Fakhry Hussein <sup>11</sup>, Mohammed Fathelrahman Adam <sup>12</sup>, Fatimah Saed Alabd Abdullah <sup>13</sup>, Wafa Kammoun Rebai <sup>14</sup>, Etwal Bou Raad <sup>15,16</sup>, Mai Hussein <sup>17,18</sup>, Shehata F. Shehata <sup>19,20</sup>, Ismail Ibrahim Ismail <sup>21</sup>, Arslan Ahmed Salam <sup>22</sup> and Dalia Samhour <sup>23</sup>



**Citation:** Ghazy, R.M.; Abdou, M.S.; Awaidy, S.; Sallam, M.; Elbarazi, I.; Youssef, N.; Fiidow, O.A.; Mehdad, S.; Hussein, M.F.; Adam, M.F.; et al. Acceptance of COVID-19 Vaccine Booster Doses Using the Health Belief Model: A Cross-Sectional Study in Low-Middle- and High-Income Countries of the East Mediterranean Region. *Int. J. Environ. Res. Public Health* **2022**, *19*, 12136. <https://doi.org/10.3390/ijerph191912136>

Academic Editors: Xinying Sun and Yibo Wu

Received: 24 August 2022

Accepted: 20 September 2022

Published: 25 September 2022

**Publisher's Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



**Copyright:** © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

- <sup>1</sup> Tropical Health Department, High Institute of Public Health, Alexandria University, Alexandria 21561, Egypt
- <sup>2</sup> Department of Epidemiology, High Institute of Public Health, Alexandria University, Alexandria 21561, Egypt
- <sup>3</sup> Health Affairs, Ministry of Health, Muscat 100, Oman
- <sup>4</sup> Department of Pathology, Microbiology and Forensic Medicine, School of Medicine, The University of Jordan, Amman 11942, Jordan
- <sup>5</sup> Department of Clinical Laboratories and Forensic Medicine, Jordan University Hospital, Amman 11942, Jordan
- <sup>6</sup> Department of Translational Medicine, Faculty of Medicine, Lund University, 22184 Malmö, Sweden
- <sup>7</sup> Institute of Public Health, College of Medicine and Health Sciences, United Arab Emirates University, AlAin 15551, United Arab Emirates
- <sup>8</sup> Department of Medical-Surgical Nursing, College of Nursing, Princess Nourah bint Abdulrahman University, Riyadh 11671, Saudi Arabia
- <sup>9</sup> School of Public Health and Research, Somali National University, Mogadishu P.O. Box 15, Somalia
- <sup>10</sup> Physiology and Physiopathology Research Team, Research Centre of Human Pathology Genomics, Faculty of Sciences, Mohammed V University, Rabat BP 8007, Morocco
- <sup>11</sup> Occupational Health and Industrial Medicine Department, High Institute of Public Health, Alexandria University, Alexandria 21526, Egypt
- <sup>12</sup> Faculty of Pharmacy, University of Science and Technology, Khartoum P.O. Box 12810, Sudan
- <sup>13</sup> Internal Medicine Department, Faculty of Medicine, Alexandria University, Alexandria 21526, Egypt
- <sup>14</sup> Institute Pasteur de Tunis, Tunis 2092, Tunisia
- <sup>15</sup> Department of Epidemiology and Population Health, American University of Beirut, Beirut P.O. Box 110236, Lebanon
- <sup>16</sup> School of Pharmacy, Lebanese International University, Beirut P.O. Box 146404, Lebanon
- <sup>17</sup> Clinical Research Administration, Alexandria Directorate of Health Affairs, Egyptian Ministry of Health and Population, Alexandria 21554, Egypt
- <sup>18</sup> Harvard Medical School, Boston, MA 02115, USA
- <sup>19</sup> Department of Family and Community Medicine, King Khalid University, Abha 62529, Saudi Arabia
- <sup>20</sup> Biostatistics Department, High Institute of Public Health, Alexandria University, Alexandria 21561, Egypt
- <sup>21</sup> Department of Neurology, Ibn Sina Hospital, Gamal Abdel Nasser Street, Sabah Medical Area, Safat 070001, Kuwait
- <sup>22</sup> National Institute of Health, Islamabad 45320, Pakistan
- <sup>23</sup> Emergency Preparedness & IHR, WHO EMRO (DS), P.O. Box 7608, Naser City 11371, Egypt
- \* Correspondence: [ramy\\_ghazy@alexu.edu.eg](mailto:ramy_ghazy@alexu.edu.eg)

**Abstract:** Coronavirus disease (COVID-19) booster doses decrease infection transmission and disease severity. This study aimed to assess the acceptance of COVID-19 vaccine booster doses in low, middle, and high-income countries of the East Mediterranean Region (EMR) and its determinants using the health belief model (HBM). In addition, we aimed to identify the causes of booster dose rejection and the main source of information about vaccination. Using the snowball and convince sampling technique, a bilingual, self-administered, anonymous questionnaire was used to collect the data from 14 EMR countries through different social media platforms. Logistic regression analysis was used to estimate the key determinants that predict vaccination acceptance among respondents. Overall, 2327 participants responded to the questionnaire. In total, 1468 received compulsory doses

of vaccination. Of them, 739 (50.3%) received booster doses and 387 (26.4%) were willing to get the COVID-19 vaccine booster doses. Vaccine booster dose acceptance rates in low, middle, and high-income countries were 73.4%, 67.9%, and 83.0%, respectively ( $p < 0.001$ ). Participants who reported reliance on information about the COVID-19 vaccination from the Ministry of Health websites were more willing to accept booster doses (79.3% vs. 66.6%,  $p < 0.001$ ). The leading causes behind booster dose rejection were the beliefs that booster doses have no benefit (48.35%) and have severe side effects (25.6%). Determinants of booster dose acceptance were age (odds ratio (OR) = 1.02, 95% confidence interval (CI): 1.01–1.03,  $p = 0.002$ ), information provided by the Ministry of Health (OR = 3.40, 95% CI: 1.79–6.49,  $p = 0.015$ ), perceived susceptibility to COVID-19 infection (OR = 1.88, 95% CI: 1.21–2.93,  $p = 0.005$ ), perceived severity of COVID-19 (OR = 2.08, 95% CI: 1.37–3.16,  $p = 0.001$ ), and perceived risk of side effects (OR = 0.25, 95% CI: 0.19–0.34,  $p < 0.001$ ). Booster dose acceptance in EMR is relatively high. Interventions based on HBM may provide useful directions for policymakers to enhance the population's acceptance of booster vaccination.

**Keywords:** COVID-19 vaccine; booster dose acceptance; health belief model; vaccine hesitancy; East Mediterranean region

## 1. Introduction

Coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome (SARS-CoV-2), is still sweeping the globe. The pattern of infection and mortality due to COVID-19 differed significantly across countries [1,2], resulting in a high burden on healthcare facilities, the global economy, and social drawbacks [2,3]. As of 19 September 2022, there had been 611,421,786 confirmed cases of COVID-19 reported to the World Health Organization (WHO), including 6,512,438 deaths [4].

COVID-19 control is based on the strength of non-pharmaceutical interventions (NPIs) and the pace of infection development or decay, the speed with which the vaccine can be rolled out, vaccine targeting and uptake, and vaccine characteristics [5]. Although there have been international debates on the effectiveness of NPIs on viral transmission [6,7], many studies have proven the effectiveness of these measures on pandemic containment [8,9]. The cumulative effect of NPIs and immunization lowered the reproduction number ( $R_0$ ) by 53% (95% confidence interval: 42–62%), whereas NPIs and vaccination reduced transmission by 35% and 38%, respectively. So, both measures should be implemented simultaneously.

Globally, a total of 12,613,484,608 vaccine doses have been delivered as of September 12, 2022 [10], in an attempt to reduce infection through transmission and so as not to rely on herd immunity alone [11]. However, infection instances continued to be documented even after receiving two doses of the COVID-19 vaccine; this was referred to as “breakthrough infections,” and it has become a serious problem [12]. The current vaccine method may not establish a significant barrier against SARS-CoV-2 infections [13,14]. Research is still ongoing to determine the causes of breakthrough infections after vaccination. The substantial reduction in antibody titers over time following vaccination has been found to be one of the causes of such breakthrough [15]. Additionally, the multiple SARS-CoV-2 variants—including the most recent B.1.1.529 strain (in South Africa), the B.1.1.7 strain (in the United Kingdom), P.1 (in Brazil), and B.1.617 (in India)—increase the likelihood of breakthrough infections [13,16].

Recent clinical investigations have shown that the frequencies of confirmed COVID-19 and severe illness dramatically decreased with the third and fourth doses of inactivated or mRNA vaccine [17]. Other research also supported the booster vaccination's ability to raise the titers of antibodies that neutralize SARS-CoV-2 variants significantly [18,19]. Consequently, experts in infectious diseases have carefully considered whether booster shots are necessary for all susceptible individuals or just a few vulnerable groups to enhance immunity levels and protect against new variations [20]. Hence, COVID-19 booster doses are expected to face rejection or hesitancy, which necessitates a thorough exploration of the underlying causes for

such attitudes [21]. One of the ten threats to global health is vaccine hesitancy, which was widely prevalent in the context of COVID-19 vaccination [22–25]. Vaccine hesitancy is defined as the unwillingness or refusal to vaccinate despite the availability of vaccines [26]. This attitude represents a threat hindering the progress made in combating vaccine-preventable illnesses [27].

The East Mediterranean region (EMR) consists of 22 countries (i.e., Yemen, United Arab Emirates (UAE), Tunisia, Syrian Arab Republic, Sudan, Somalia, Qatar, Pakistan, Oman, Occupied Palestine Territory, Morocco, Libya, Lebanon, Kuwait, Jordan, Iraq, Iran, Egypt, Djibouti, Bahrain, and Afghanistan). These countries are of different income levels and health system capacities [28]. This gap is reflected in vaccination coverage; where the number of fully vaccinated subjects/100 population ranges from 1.58 in Yemen, 44.68, 54.0, and 59.4 in Jordan, Tunisia, and Pakistan respectively, peaking at 99.0 in the UAE. This vaccine coverage is much lower upon exploring the fraction of populations who received booster doses of COVID-19 vaccines, as it ranges from 0 to 51.6/100 people [10]. Regarding COVID-19 vaccine hesitancy in the EMR, an early study showed that only 26.7% of 4474 study participants from 13 countries were confident about the vaccination. The confidence was higher in high-income compared to low- and middle-income countries [29].

Studies about the acceptance of COVID-19 vaccine booster doses in the EMR are scarce. A study in Jordan reported that about 50% of the population have concerns about the side effects of vaccination, which might prevent them from receiving booster shots of vaccines, and 45.3% thought that receiving a third dose of the vaccine would exacerbate the side effects [30]. Higher acceptance of booster vaccination was reported among Saudi healthcare workers. Specifically, about 71.1% of 2059 healthcare workers accepted booster doses, with the following factors being significantly associated with vaccine booster dose acceptance: having comorbid conditions, higher educational level, high income, and being single [31].

In this study, we aimed to explore the acceptance of COVID-19 vaccine booster doses in low, middle, and high-income countries of the EMR and its determinants by using the Health Belief Model (HBM) constructions. The Health Belief Model is one of the most popular models for analyzing individuals' behavior towards vaccination against COVID-19 [32]. The model hypothesizes that several variables influence the individual's health-related behavior such as cues to action, self-efficacy, and perception of susceptibility, severity, benefits, and barriers [33]. In addition, we intended to identify the main causes of booster dose rejection and the sources from which the population received information about vaccination. The findings of this study can help in developing strategies for actions to upscale COVID-19 vaccine booster dose acceptance in EMRs.

## 2. Materials and Methods

### 2.1. Study Setting

A cross-sectional method was adopted to collect data from 14 EMR countries from March to June 2022. Based on the World Bank classification, the countries chosen were either low-income (Sudan, Somalia), middle-income (i.e., Egypt, Tunisia, Morocco, Libya, Jordan, Lebanon, and Pakistan), or high-income countries (Saudi Arabia, Kuwait, UAE, and Oman). An anonymous online survey was distributed by a team of researchers via social media platform and messaging platforms.

### 2.2. Study Population and Sampling Methods

A convenience and snowball sampling techniques were used to recruit the participants who must meet the following eligibility criteria for participation in this study: aged 18 years or older, had received two doses of the COVID-19 vaccine (or a single dose of the Johnson & Johnson vaccine), had a mobile phone or computer, educated to self-complete the survey, and residents in the EMR during the COVID-19 pandemic.

### 2.3. Sample Size

Epi-info 7 was used to estimate the minimum size of the required sample. With a 5% margin of error, 95% confidence level, 50% response rate, and a previously estimated rate of 60.0% for COVID-19 vaccine acceptance, a sample size of 642 (from the EMR) was considered sufficient. However, the sample size was doubled to compensate for stratification during the analysis of data and enhance the power of the study findings.

### 2.4. Tools of Data Collection

A questionnaire of two domains was created to collect the data. The first domain collected (i) sociodemographic and health condition data (i.e., age, sex, education, marital status, nationality, country of residency, body weight, height, previous COVID-19 infection, COVID-19 among relatives, history of chronic diseases, and immunocompromising diseases) and (ii) attitude towards the booster dose (I received the booster dose, planning to receive the booster dose, will not take any more doses). The second domain (HBM questionnaire) included 11 items that were used to assess the perceptions of COVID-19 infection and booster vaccination.

The HBM consists of the following 6 domains:

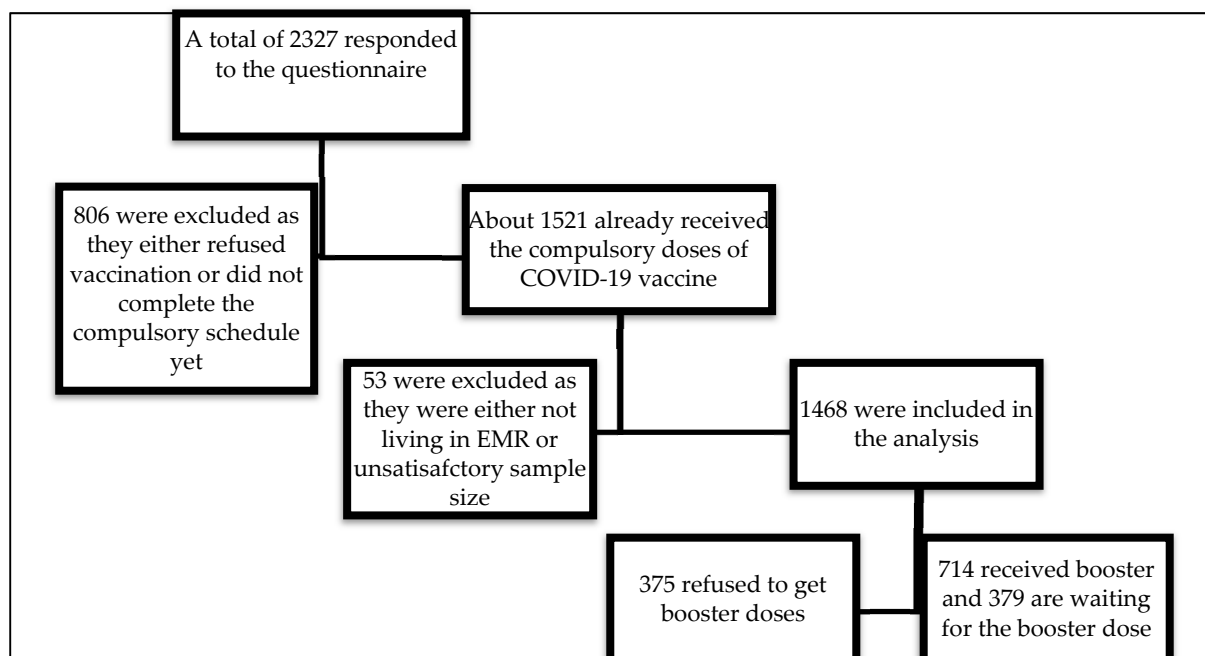
(i) Perceived susceptibility to COVID-19 infection: it consists of two items and refers to one's beliefs about the chances of worsening his/her health condition. (ii) Perceived severity of COVID-19 which refers to one's feeling about the seriousness of his/her health condition, ability to worsen, or failure to treat the illness. This item also consists of two items. Moreover, the perceived severity domain includes one's evaluation of medical and clinical outcomes such as fatality, infirmity, and discomfort, as well as potential consequences on her/his daily social activities such as the effects of their medical condition on work productivity, family activities, and social interactions and relations. According to the HBM, perceived threats were defined as the combination of perceived susceptibility and perceived severity. Thus, the first and second domains can be applied under one domain labeled "perceived threats". (iii) Perceived benefit of COVID-19 booster indicates that the individual's beliefs about the perceived benefits of the various available actions for reducing the disease threat are influenced by his/her perception of the threat, regardless of whether or not that perception ended with a behavior change. This domain consists of three items, (iv) a perceived barrier to receiving COVID-19 booster doses, which indicates the impending negative consequences and aspects of a particular health action that may considerably act as obstacles to engagement in recommended health behaviors. This domain consists of three items. As per the HBM, perceived susceptibility and perceived benefits could only be potentiated by other independent factors, particularly by clues used to prompt actions, namely "cues to action", such as physical condition, or by environmental factors, such as media. (v) self-efficacy has been elaborated on by the HBM as an essential factor that may encourage certain behavior. Moreover, it is defined as "the conviction that one can successfully execute the behavior required to produce the outcomes" [34].

The responses to the questionnaire's items were aggregated as follows: high (high/very high), neutral, and low (low/very low). All domains of the HBM questionnaire had an acceptable level of validity as Cronbach's Alpha value was  $\geq 0.6$ , except the perceived barrier was 0.59 [35]. Of the six dimensions that make up the HBM model, five of which are positive and one of which is negative. According to the model, behavior is more likely to be present among people who may think there will be little or no obstacles to adopting behaviors; that it will lower the chance of a negative health outcome; that it will have a significant negative impact on their health; and if they think they are vulnerable to it [36].

The questionnaire was administered in Arabic (for the general population) and English (for healthcare professionals or others) to eliminate the difficulties of language as previously suggested [35]. The face validity of the questionnaire was investigated before administration.

### 2.5. Plan of Data Collection

An electronic form of the questionnaire was designed using Google Forms and distributed via different social media (Facebook and Twitter) and messaging platforms (WhatsApp and emails) from March to June 2022. Before actual data collection, the research team tested the feasibility and accessibility of the online tool in a pilot study. Each collaborator was asked to submit at least two responses to determine the time required for completing the survey and the feasibility of the study. A total of 2327 individuals responded to the questionnaire. About 806 (34.6%) were excluded as they either did not receive the vaccination at all or did not complete the compulsory schedule of COVID-19 vaccination. Another 53 (2.3%) responses were omitted as the responders were not living in EMR countries or the responses were unsatisfactory. Finally, 1468 were included in the analysis; 375 (25.5%) refused to get the booster, 739 (50.3%) received booster doses, and 387 (26.4%) were willing to get the booster doses. In Figure 1, we aggregated data on those who have already received booster doses and those who are willing to receive booster doses, who represented 74.5% (1093/1468).



**Figure 1.** The flow chart of the sampling process.

### 2.6. Ethical Considerations and Approval

The Ethics Committee of the High Institute of Public Health, Alexandria University, Egypt approved the study. Information about the study's purpose, anonymity, confidentiality, voluntary participation, and privacy statements was provided on the survey cover page to all participants who were prompted "to agree" or "not to agree" to participate in the study. Those who clicked "I agree to participate" were able to access the questionnaire. Data were protected and saved in a password-accessible computer available only to the principal investigator.

### 2.7. Statistical Analysis

The data were managed and analyzed using the R 4.2.1 software (R Foundation for Statistical Computing, Vienna, Austria). Numerical variables were presented using mean  $\pm$  standard deviation (SD), whereas nominal and categorical variables were expressed as a percentage (%). A Chi-Square test was used to assess the association between the nonnumerical variables, and the responses were categorized into Yes or No based on receiving COVID-19 booster doses. An independent t-test was performed to compare

the difference between the means of two independent groups. Cronbach's alpha test was deployed to assess the internal consistency of the domains and their items. A binary logistic regression analysis was conducted to estimate the significant predictors' odds ratios, and a confidence interval of 95% (OR, 95% CI) was reported. The dependent variable was the actual or virtual acceptance of COVID-19 booster vaccination, which was defined based on the following questions: "Have you received the booster dose of COVID-19 vaccine" or "Will you get the booster dose of COVID-19 vaccine" (Yes/No)". A  $p$ -value  $< 0.05$  was considered statistically significant.

### 3. Results

#### 3.1. Respondents' Sociodemographic Characteristics

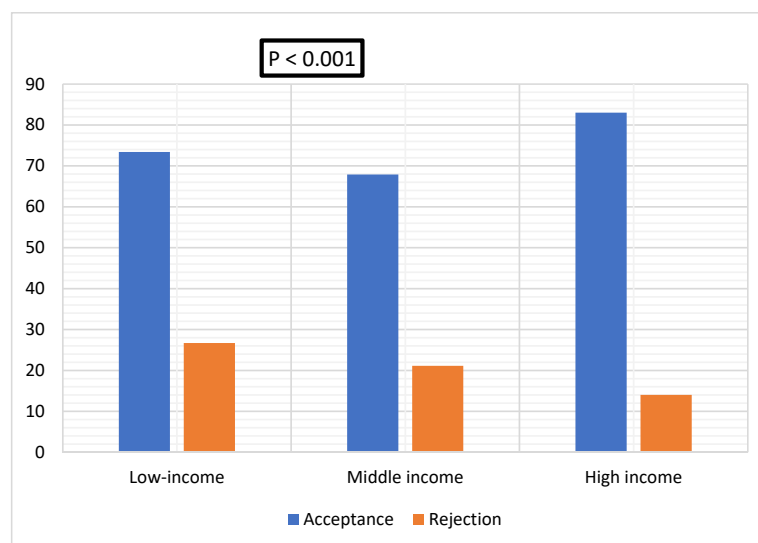
The mean age of the respondents was  $36.53 \pm 13.45$ , ranging from 18–88 years; females represented 62.7% (920); more than half of them were married 55.2%, (811); nearly one half 48.0% (705) had a university degree; about one-third 35.8% (526) were working in the medical field; 16.1% (237) had chronic diseases; and those who had COVID-19 infection before accounted for 51.1% (750); those who had relatives that had COVID-19 infection represented 86.4% (1268); and those with relatives who were immunocompromised and living in the vicinity of the participant made up 14.3% (210) of respondents (Table 1).

**Table 1.** Sociodemographic criteria and medical conditions,  $n = 1468$ .

| Variables                           |                                   | n (%)                         |
|-------------------------------------|-----------------------------------|-------------------------------|
| Sex                                 | Males                             | 548 (37.3)                    |
|                                     | Females                           | 920 (62.7)                    |
| Age                                 | Mean $\pm$ SD (min-max)           | $36.53 \pm 13.45$ (18.0–88.0) |
|                                     | Single                            | 596 (40.6)                    |
| Marital status                      | Married                           | 811 (55.2)                    |
|                                     | Divorced                          | 42 (2.9)                      |
|                                     | Widow                             | 19 (1.3)                      |
|                                     | Diploma                           | 87 (5.9)                      |
| Education                           | Secondary education               | 171 (11.6)                    |
|                                     | University students               | 705 (48.0)                    |
|                                     | Postgraduate                      | 505 (34.4)                    |
|                                     | I do not work                     | 186 (12.7)                    |
| Working                             | Retired                           | 50 (3.4)                      |
|                                     | Students                          | 293 (20.0)                    |
|                                     | Working in the medical field      | 526 (35.8)                    |
|                                     | Working outside the medical field | 413 (28.1)                    |
| Chronic Disease                     | Yes                               | 237 (16.1)                    |
|                                     | No                                | 1231 (83.9)                   |
| Previous COVID-19 infection         | Yes                               | 750 (51.1)                    |
|                                     | No                                | 718 (48.9)                    |
| A relative had a COVID-19 infection | Yes                               | 1268 (86.4)                   |
|                                     | No                                | 200 (13.6)                    |
| Immunocompromised relative          | Yes                               | 210 (14.3)                    |
|                                     | No                                | 1258 (85.7)                   |

#### 3.2. COVID-19 Booster Dose Acceptance in Low-, Middle, and High-Income Countries

There was a significant difference in booster dose acceptance among the included EMR countries, being the highest in low-income countries at 73.4% (141/192), and lowest in middle-income countries at 17.0% (480/707) at  $p < 0.001$  Figure 2.



**Figure 2.** Acceptance of COVID-19 vaccine booster dose across different countries of the East Mediterranean Region based on their income level.

### 3.3. Characteristics of Vaccinated and Non-Vaccinated Participants

Acceptance of the COVID-19 vaccine was reported more frequently among males than females (79.4% vs. 71.5%),  $p = 0.001$ . The mean age of respondents who accepted vaccination was significantly older than those who rejected vaccination ( $37.5 \pm 13.8$  vs.  $33.9 \pm 12.0$ , respectively,  $p < 0.001$ ). The mean BMI of respondents who accepted booster doses tended to be higher than those who rejected ( $26.2 \pm 5.5$  vs.  $25.6 \pm 5.8$ ). However, this difference was insignificant ( $p = 0.075$ ). Being married was significantly associated with booster dose acceptance, as 77.7% of those who were married versus 69.6% of those who were single accepted booster dose, with  $p = 0.003$ . About 71.1% (533/750) of respondents -19 previously infected with COVID vs. 78.0 (560/718) of non-previously infected respondents accepted booster doses ( $p = 0.003$ ). About 75.5% (959/1258) of those who accepted vaccination had no immunocompromised person living in the same context compared to 68.1% (143/210) of participants who had immunocompromised relatives ( $p = 0.028$ ). Neither occupation, chronic diseases, nor having a relative who was infected with COVID-19 were associated with booster dose acceptance (Table 2).

**Table 2.** Comparison of different characteristics among vaccinated and non-vaccinated participants.

| Dependent (Vaccination) |                     | Total | Accept Vaccination (n = 1093) |      | Reject Vaccination (n = 375) |      | p      |
|-------------------------|---------------------|-------|-------------------------------|------|------------------------------|------|--------|
|                         |                     |       | n                             | %    | n                            | %    |        |
| Sex                     | Female              | 920   | 658                           | 71.5 | 262                          | 28.5 | 0.001  |
|                         | Male                | 548   | 435                           | 79.4 | 113                          | 20.6 |        |
| Age                     | Mean $\pm$ SD       |       | $37.5 \pm 13.8$               |      | $33.9 \pm 12.0$              |      | <0.001 |
| Body mass index         | Mean $\pm$ SD       |       | $26.2 \pm 5.5$                |      | $25.6 \pm 5.8$               |      | 0.075  |
| Marital status          | Married             | 811   | 630                           | 77.7 | 181                          | 22.3 | 0.002  |
|                         | Single #            | 657   | 463                           | 69.6 | 194                          | 30.4 |        |
| Education               | Secondary education | 171   | 143                           | 83.6 | 28                           | 16.4 | 0.002  |
|                         | Diploma/Art         | 87    | 73                            | 83.9 | 14                           | 16.1 |        |
|                         | University          | 705   | 517                           | 73.3 | 188                          | 26.7 |        |
|                         | Higher Education    | 505   | 360                           | 71.3 | 145                          | 28.7 |        |

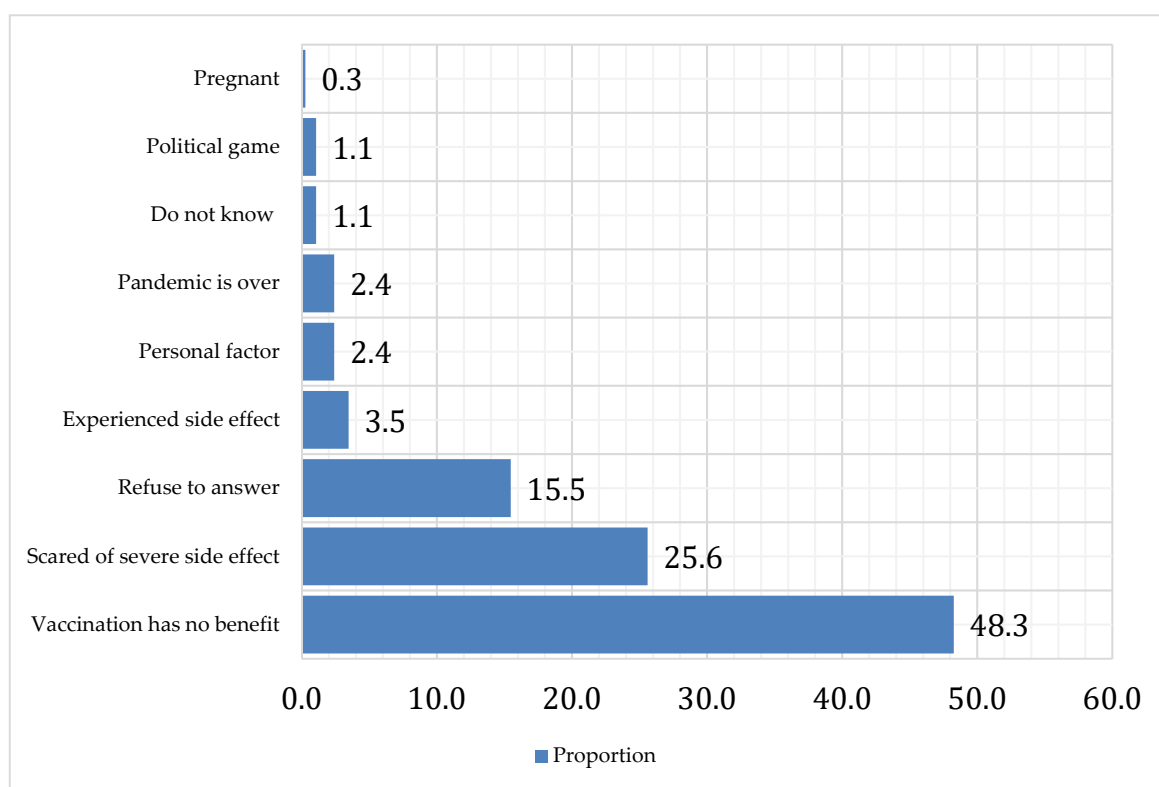
Table 2. Cont.

| Dependent<br>(Vaccination)     |     | Total | Accept Vaccination<br>(n = 1093) |      | Reject Vaccination<br>(n = 375) |      | p     |
|--------------------------------|-----|-------|----------------------------------|------|---------------------------------|------|-------|
|                                |     |       | n                                | %    | n                               | %    |       |
| Previous COVID-19<br>infection | No  | 718   | 560                              | 78.0 | 158                             | 22.0 | 0.003 |
|                                | Yes | 750   | 533                              | 71.1 | 217                             | 28.9 |       |
| Immunocompromised<br>relative  | No  | 1258  | 950                              | 75.5 | 308                             | 24.5 | 0.028 |
|                                | Yes | 210   | 143                              | 68.1 | 67                              | 31.9 |       |

# Single includes widow, divorced, and single.

### 3.4. Leading Causes behind Booster Dose Rejection

The leading causes behind booster dose rejection were the beliefs that the booster vaccine has no benefit 48.35% (181/375) and that it has severe side effects 25.6% (96/375). About 15.5% (58/375) refused to answer this question. Figure 3.



**Figure 3.** The leading causes behind COVID-19 booster dose vaccine rejection among the participants.

### 3.5. Source of Information about COVID-19

Asking participants about the primary sources of information about COVID-19 disease and vaccination revealed that the most frequently used sources were social media 56.0% (646/1468), the Center for Diseases Prevention and Control (CDC) website 53.6% (787/1468), followed by the Ministry of Health (MOH) website 41.3% (905/1468). However, 79.3% (718/905) of those who did follow the information provided by the MOH website accepted booster doses compared to 66.6% (375/863) of those who did not follow this source of information; this difference was statistically significant ( $p < 0.001$ ) (Table 3).

**Table 3.** Source of information about COVID-19.

| Dependent: Vaccination     |     | Total<br>(n = 1468) | Accept Vaccination |       | Reject Vaccination |      | p      |
|----------------------------|-----|---------------------|--------------------|-------|--------------------|------|--------|
|                            |     |                     | n                  | %     | n                  | %    |        |
| Social media               | No  | 646 (44.0)          | 469                | 72.6  | 177                | 27.4 | 0.166  |
|                            | Yes | 822 (56.0)          | 624                | 75.9  | 198                | 24.1 |        |
| Relative and friends       | No  | 1122 (76.4)         | 835                | 74.4  | 287                | 25.6 | 1      |
|                            | Yes | 346 (23.6)          | 258                | 74.6  | 88                 | 25.4 |        |
| Literature                 | No  | 816 (55.6)          | 613                | 75.1  | 203                | 24.9 | 0.551  |
|                            | Yes | 652 (45.4)          | 480                | 73.6  | 172                | 26.4 |        |
| Ministry of Health website | No  | 863 (58.7)          | 375                | 66.6  | 188                | 33.4 | <0.001 |
|                            | Yes | 905 (41.3)          | 718                | 79.3  | 187                | 20.7 |        |
| CDC website                | No  | 681 (46.4)          | 854                | 74.0  | 300                | 26.0 | 0.492  |
|                            | Yes | 787 (53.6)          | 239                | 76.1  | 75                 | 23.9 |        |
| WHO website                | No  | 1154 (78.6)         | 492                | 72.3  | 189                | 27.8 | 0.081  |
|                            | Yes | 314 (21.4)          | 601                | 76.34 | 186                | 23.6 |        |
| Other                      | No  | 1452 (98.9)         | 1082               | 74.6  | 369                | 25.4 | 0.517  |
|                            | Yes | 17 (1.1)            | 11                 | 64.7  | 6                  | 35.3 |        |

CDC: Center for Diseases Prevention and Control, the *p*-value was significant if <0.05, and the chi-square was the used statistical test.

### 3.6. Determinants of Booster Dose Acceptance

All domains of the HBM (i.e., perceived susceptibility, perceived severity, perceived benefit, perceived barriers, and perceived efficacy) were statistically significant across vaccinated and unvaccinated groups ( $p < 0.05$ ) except for question 13 (cues to action) as shown in Table 4. The HBM questionnaire has a Cronbach's alpha of 0.68, and it ranged from 0.63 to 0.73 for each question.

**Table 4.** Perception of the booster doses based on the health belief model.

| Dependent: Vaccination   | Question/Category                                                                                  |         | Total | Accept Vaccination |      | Reject Vaccination |      | p      | Cronbach Alpha |
|--------------------------|----------------------------------------------------------------------------------------------------|---------|-------|--------------------|------|--------------------|------|--------|----------------|
|                          |                                                                                                    |         | n     | n                  | %    | n                  | %    |        |                |
| Perceived susceptibility | Q1: I think there is a risk of COVID-19 infection                                                  | High    | 601   | 74                 | 12.3 | 527                | 87.7 | <0.001 | 0.65           |
|                          |                                                                                                    | Low     | 387   | 137                | 35.4 | 250                | 64.6 |        |                |
|                          |                                                                                                    | Neutral | 480   | 164                | 34.2 | 316                | 65.8 |        |                |
|                          | Q2: I think COVID-19 variants have a higher risk of infection than the existing strains            | High    | 600   | 93                 | 15.5 | 507                | 84.5 |        | 0.65           |
|                          |                                                                                                    | Low     | 447   | 157                | 35.1 | 290                | 64.9 |        |                |
|                          |                                                                                                    | Neutral | 421   | 125                | 29.7 | 296                | 70.3 |        |                |
| Perceived severity       | Q3: I think COVID-19 infection is a severe disease                                                 | High    | 709   | 113                | 15.9 | 596                | 84.1 | <0.001 | 0.65           |
|                          |                                                                                                    | Low     | 304   | 127                | 41.8 | 177                | 58.2 |        |                |
|                          |                                                                                                    | Neutral | 455   | 135                | 29.7 | 320                | 70.3 |        |                |
|                          | Q4: I agree that COVID-19 variants can cause more severe illness than the existing strains         | High    | 553   | 112                | 20.3 | 441                | 79.7 |        | 0.66           |
|                          |                                                                                                    | Low     | 391   | 138                | 35.3 | 253                | 64.7 |        |                |
|                          |                                                                                                    | Neutral | 524   | 125                | 23.9 | 399                | 76.1 |        |                |
| Perceived benefit        | Q5: I believe the COVID-19 boosters are effective against early circulating COVID-19 strains       | High    | 654   | 43                 | 6.6  | 611                | 93.4 | <0.001 | 0.63           |
|                          |                                                                                                    | Low     | 399   | 219                | 54.9 | 180                | 45.1 |        |                |
|                          |                                                                                                    | Neutral | 415   | 113                | 27.2 | 302                | 72.8 |        |                |
|                          | Q6: I believe the COVID-19 boosters are effective to extend protection against COVID-19 infection. | High    | 699   | 54                 | 7.7  | 645                | 92.3 |        | 0.63           |
|                          |                                                                                                    | Low     | 369   | 221                | 59.9 | 148                | 40.1 |        |                |
|                          |                                                                                                    | Neutral | 400   | 100                | 25.0 | 300                | 75.0 |        |                |
|                          | Q7: I believe the COVID-19 boosters are effective against COVID-19 variants                        | High    | 612   | 39                 | 6.4  | 573                | 93.6 | <0.001 | 0.63           |
|                          |                                                                                                    | Low     | 421   | 229                | 54.4 | 192                | 45.6 |        |                |
|                          |                                                                                                    | Neutral | 435   | 107                | 24.6 | 328                | 75.4 |        |                |

Table 4. Cont.

| Dependent: Vaccination | Question/Category                                                                   |              | Total    | Accept Vaccination |      | Reject Vaccination |      | <i>p</i> | Cronbach Alpha |
|------------------------|-------------------------------------------------------------------------------------|--------------|----------|--------------------|------|--------------------|------|----------|----------------|
|                        |                                                                                     |              | <i>n</i> | <i>n</i>           | %    | <i>n</i>           | %    |          |                |
| Perceived barriers     | Q8: I think COVID-19 vaccine boosters are safe                                      | High         | 594      | 39                 | 6.6  | 555                | 93.4 | <0.001   | 0.65           |
|                        |                                                                                     | Low          | 426      | 228                | 53.5 | 198                | 46.5 |          |                |
|                        |                                                                                     | Neutral      | 448      | 108                | 24.1 | 340                | 75.9 |          |                |
|                        | Q9: I am worried about the serious adverse reaction after vaccination               | High         | 411      | 197                | 47.9 | 214                | 52.1 | <0.001   | 0.67           |
|                        |                                                                                     | Low          | 711      | 98                 | 13.8 | 613                | 86.2 |          |                |
|                        |                                                                                     | Neutral      | 346      | 80                 | 23.1 | 266                | 76.9 |          |                |
|                        | Q10: I know persons had severe side effects after being vaccinated                  | High         | 362      | 158                | 43.6 | 204                | 56.4 | <0.001   | 0.68           |
|                        |                                                                                     | Low          | 788      | 126                | 16.0 | 662                | 84.0 |          |                |
|                        |                                                                                     | Neutral      | 318      | 91                 | 28.6 | 227                | 71.4 |          |                |
| Perceived Efficacy     | Q11: It is easy for me to get the COVID-19 vaccine if I wanted to                   | High         | 1056     | 251                | 23.8 | 805                | 76.2 | 0.042    | 0.67           |
|                        |                                                                                     | Low          | 120      | 35                 | 29.2 | 85                 | 70.8 |          |                |
|                        |                                                                                     | Neutral      | 292      | 89                 | 30.5 | 203                | 69.5 |          |                |
| Cues to action         | Q12: Did you use to have confirmed or suspected cases in your daily close contacts? | No           | 772      | 595                | 77.1 | 177                | 22.9 | 0.018    | 0.70           |
|                        |                                                                                     | Yes          | 696      | 498                | 71.6 | 198                | 28.4 |          |                |
|                        |                                                                                     | All Types    | 321      | 249                | 77.6 | 72                 | 22.4 |          |                |
|                        | Q13: Do you know about the following COVID-19 variants?                             | Four Types   | 115      | 82                 | 71.3 | 33                 | 28.7 | 0.257    | 0.73           |
|                        |                                                                                     | I Don't Know | 160      | 123                | 76.9 | 37                 | 23.1 |          |                |
|                        |                                                                                     | One Type     | 354      | 270                | 76.3 | 84                 | 23.7 |          |                |
|                        |                                                                                     | Three Types  | 198      | 144                | 72.7 | 54                 | 27.3 |          |                |
|                        |                                                                                     | Two Types    | 320      | 225                | 70.3 | 95                 | 29.7 |          |                |

*p*-value was significant if <0.05, and chi-square was the used statistical test.

### Determinants of Booster Dose Acceptance Using Multivariable Regression Analysis

Figure 4 depicts a multivariable regression analysis which revealed that age (OR = 1.02, 95% CI: 1.01–1.04, *p* = 0.002), information source as Ministry of Health and population (OR = 1.38, 95% CI: 1.6–1.80, *p* = 0.015) were significant determinants of COVID-19 booster dose acceptance. Regarding the HBM, perceived susceptibility to COVID-19 infection (OR = 1.88, 95% CI: 1.21–2.93, *p* = 0.005), perceived severity of COVID-19 (OR = 2.08, 95% CI: 1.37–3.16, *p* = 0.001), and perceived risk of side effects (OR = 0.25, 95% CI: 0.19–0.34, *p* < 0.001) were the significant predictors of COVID-19 booster dose acceptance.

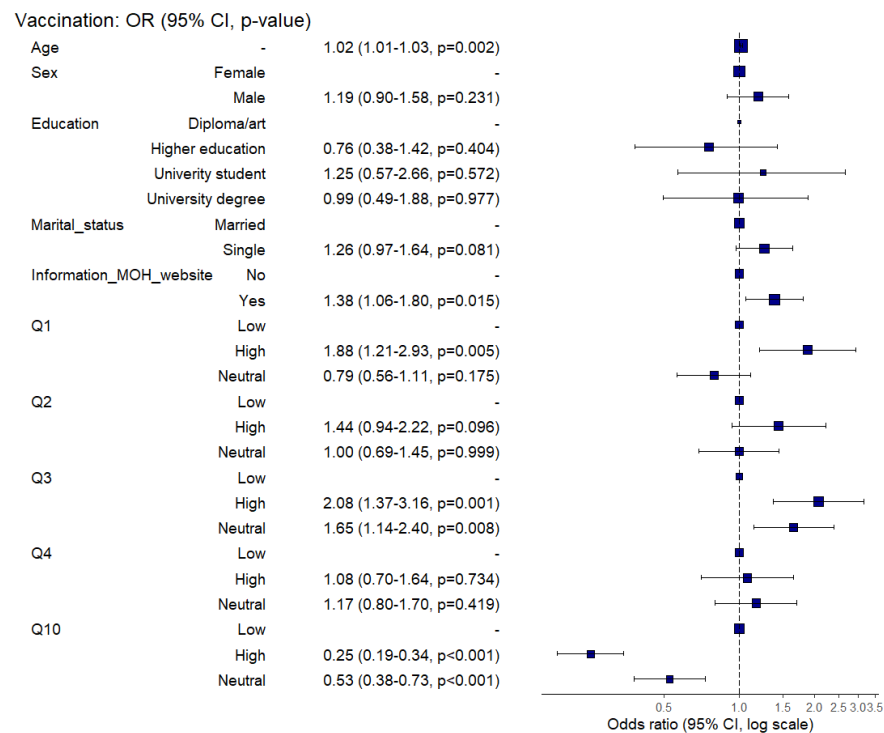


Figure 4. Forest plot of the adjusted odds ratios; the dependent factor is vaccine acceptance.

## 4. Discussion

### 4.1. Booster Dose Acceptance

The present study demonstrated a high COVID-19 vaccination booster acceptance rate (74.46%) among the population in the EMR. This figure is substantially higher than a recently published study by Abuzaid et al., [37]. They reported that 60.2% of the respondents accepted the booster dose of the COVID-19 vaccine, and 20.4% were hesitant to receive the vaccination. We hypothesize that this difference may be related to the various research settings and scenarios. They only conducted their study in five countries (Egypt, Iraq, Palestine, Saudi Arabia, and Sudan) in November and December 2021. In comparison, we included around 14 countries from different time periods. Furthermore, our sample was more representative as we included countries from North Africa (Tunisia and Morocco). Similarly, a higher booster dose acceptance rate (84.4%) was observed among the Chinese population aged 18–59 years [38]. Interestingly, Qin et al., [39] found that 93.7% of study participants accepted the booster dose of the vaccination. It is important to note that the greater public expectations for boosters to meet the new challenges posed by variant strains and the observed rising trend in COVID-19 vaccine acceptance may contribute to the higher booster acceptance rate. On other hand, Al-Qerem et al., [40] reported that almost half of the participants, 44.6% (n = 915), of Jordanian adults who have completed their current immunization schedule expected to get the COVID-19 booster dosage.

### 4.2. Acceptance Rate in Low-Middle, and High-Income Countries

In the current study, vaccine acceptance was significantly higher in high-income countries compared to low- and middle-income countries. Indeed, high-income countries received more doses from manufacturers in order to vaccinate a larger proportion of their population. On the other hand, Arce et al., [41] reported that participants in low- and medium-income countries have a stronger readiness to take vaccines but limited access to them, whereas high-income countries have adequate access to vaccines but high levels of hesitation against taking a vaccination. We speculate that in this work we already assessed the actual booster and intentional acceptance of booster doses, while Arce and his colleagues assessed the intentional acceptance of the vaccine. Moreover, the context was different as we assessed booster dose acceptance while they measured acceptance to first and second doses.

### 4.3. Determinants of Booster Dose Acceptance

In our univariate analysis, being female, younger age, being single, having a university degree or being postgraduate, and previous COVID-19 infection were significantly associated with booster dose acceptance. However, in multiple regression, age and the information provided by the Ministry of Health were the only significant determinants of vaccine acceptance. On the other hand, Lai et al., [38] reported that increased odds of booster acceptance were associated with prior COVID-19 vaccination, being young (18–30 vs. 41–50), lower educational attainment, employment, and belonging to a priority group for vaccination. The differences in sociodemographic traits between vaccination acceptability and booster acceptability require more research. This study's findings on the relationships between sociodemographic traits and booster acceptance could be a starting point for developing booster-targeted immunization programs to increase coverage.

### 4.4. Health Belief Model

We used the HBM to predict booster dose vaccine acceptance in the current study, and the questionnaire has a satisfactory level of internal consistency among the studied sample. In line of previous studies, our study findings showed that the HBM aspects served as a valuable framework for this study's assessment of participants' attitudes concerning a booster dose of the COVID-19 vaccination. In the univariate analysis, except for question 13, all items of all constructs of the HBM were significantly associated with booster dose acceptance. In contrast, in the multivariable analysis, perceived susceptibility, perceived

severity, and perceived barriers were significant predictors of booster dose acceptance. For example, Wang et al., [42] found that five dimensions of the HBM were significantly associated with COVID-19 vaccine acceptance in China. Additionally, a study conducted by Lai et al. [38] suggested that perceived benefits and perceived barriers to vaccination were important dimensions associated with accepting COVID-19 boosters. On the contrary, Quin et al., [39] found that cues to action were the most significant predictor of vaccine acceptance. So, we can conclude that the HBM can be used to assess the population's beliefs towards the acceptance of COVID-19 booster doses.

#### 4.5. Causes of COVID-19 Vaccine Rejection

Our study aimed to look into the individuals who were hesitant to receive a COVID-19 vaccine booster to better understand the contributing factors. Interestingly, we found that most of them thought that booster doses had no benefit, and about one-fourth refused vaccination as they witnessed severe side effects among vaccinated individuals. A prior study by Al-Qerem et al., [40], similarly, found that the most frequently stated reasons for participants' reluctance to receive the COVID-19 vaccine booster dose were that they believed the benefits of the booster dose were not scientifically proven, followed by the belief that there will be no need to take the booster dose for at least a year as they had received it recently, and there is no need for a booster as they were infected with COVID-19.

In the same vein, Lin et al., [43] found that among the Chinese population, those who were hesitant to receive booster doses of the vaccination expressed concern about the vaccine's side effects. However, data from clinical trials proved vaccine efficacy and safety [44–46].

#### 4.6. Source of Information about Vaccination

Infodemic have a negative impact on the COVID-19 pandemic in terms of the increased frequency of self-treatment, [47] non-compliance to NPIs, and vaccine rejection [48]. It is worth noting that, in this study, social media was the most important source of information about COVID-19 and vaccination, while the information provided by the Ministry of Health had a significant effect on vaccine acceptance in the multivariable analysis. These commonly used media channels can be utilized to deliver accurate health messages about the safety and immunogenicity of vaccination. This approach may reduce the fear of those who were hesitant. Moreover, these media can reflect the attitude of the population towards immunization [49]. One of the important messages that should be delivered is that the principal objective of vaccination during the COVID-19 pandemic continues to prevent hospitalizations, life-threatening illnesses, and death. Therefore, a third dose of the COVID-19 vaccination may only be required if evidence of insufficient protection against these negative outcomes over time is present. A third dosage may be necessary depending on the target group, the type of vaccine used, the prevalence of SARS-CoV-2, particularly important SARS-CoV-2 variants, and the level of exposure [50]. Based on this fact, Jairoun et al., [51] assessed the population's knowledge and attitude, and the acceptance of the COVID-19 vaccination booster in the UAE. The average knowledge score and attitude score among 642 participants were 44.6% and 70.2%. Knowledge level was higher among postgraduates, healthcare workers, participants with relatives infected with COVID-19, participants infected with COVID-19, and participants who had received the first two doses of the COVID-19 vaccine [51].

Finally, although the COVID-19 pandemic has been successfully controlled in many countries, SARS-CoV-2 still seriously threatens the world's health [52]. Indeed, vaccine acceptance has a detrimental effect on preventing and controlling infectious diseases and makes it harder to build herd immunity. Thus, it is essential to lower people's vaccine hesitancy to develop an immunological defense against SARS-CoV2 infections [53]. Understanding people's vaccination intentions is a crucial step to increasing immunization rates globally, especially in poorer nations [52].

#### 4.7. Strengths and Limitations

There are several limitations to this study. First, due to the intrinsic disadvantages of cross-sectional online surveys, a sampling bias may exist to limit the representativeness of the results [54]. Second, self-reported data could be skewed by recall bias and a propensity to present socially desirable outcomes. Third, study participants were recruited through a non-random sampling method; this may affect the external validity and generalization. Fourth, the sample collected from countries may be not representative of the situation of the country; however, the objective was to assess whether there was a difference among countries based on their socioeconomic level or not. Fifth, about one-third of respondents were working in the medical field. This may represent a source of selection bias. Finally, there exist inherent problems with the HBM itself. The HBM does not take into consideration a person's attitudes, beliefs, or other personal factors that influence whether they accept a healthy behavior. Habitual behavior is not taken into account by the HBM, which may influence the decision to adopt a suggested action (e.g., smoking). The HBM does not account for actions taken for social acceptance, environmental, or economic considerations that can support or discourage the advised course of action. Furthermore, the HBM assumes everyone has equal access to knowledge about the condition or disease. However, to our knowledge, this is the first study in the EMR that used the HBM to assess vaccine acceptance in the region. This study included 14 of the 22 countries in the region based on different income levels reflecting the heterogeneity of the population in the region.

#### 5. Conclusions

A third dose of the COVID-19 vaccination was acceptable to 74.47% of the EMR inhabitants in this regional cross-sectional study. Acceptance behaviors, increased age and the HBM construct were highly associated. However, there may be some reluctance due to public skepticism regarding the safety and efficacy of current vaccines in practical settings. Our findings can therefore assist policymakers in creating more precise and scientific roll-out plans for the third COVID-19 vaccine, which is crucial when a further outbreak is still conceivable.

**Author Contributions:** Conceptualization, R.M.G. and M.S.A.; Methodology, R.M.G., M.S.A. and M.F.H.; Software, R.M.G. and W.K.R.; Formal Analysis, R.M.G., F.S.A.A., A.A.S. and M.F.A.; Resources, O.A.F.; Data Curation, R.M.G., M.S.A. and M.F.H.; Writing—Original Draft Preparation, R.M.G., D.S., N.Y., S.A., I.E. and M.S.; Writing—Review & Editing, R.M.G., N.Y., S.A., I.E., M.S. and M.H.; Visualization, R.M.G., I.I.I. and E.B.R.; Supervision, D.S., R.M.G. and S.M.; Project Administration, D.S., R.M.G. and S.F.S.; Funding Acquisition, N.Y. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of the High Institute of Public Health, Alexandria University, Egypt (5/2022).

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** Data are available upon request by mailing the first author.

**Acknowledgments:** This study was supported by Princess Nourah bint Abdulrahman University Researchers Supporting Project number (PNURSP2022R177). Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia. The research team expresses their deep thanks to the study participants for providing their time and sharing in this study.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

- Hassaan, M.A.; Abdelwahab, R.G.; Elbarky, T.A.; Ghazy, R.M. GIS-based analysis framework to identify the determinants of COVID-19 incidence and fatality in Africa. *J. Prim. Care Community Health* **2021**, *12*, 21501327211041208. [CrossRef] [PubMed]
- Asem, N.; Ramadan, A.; Hassany, M.; Ghazy, R.M.; Abdallah, M.; Ibrahim, M.; Gamal, E.M.; Hassan, S.; Kamal, N.; Zaid, H. Pattern and determinants of COVID-19 infection and mortality across countries: An ecological study. *Heliyon* **2021**, *7*, e07504. [CrossRef] [PubMed]
- Lenzen, M.; Li, M.; Malik, A.; Pomponi, F.; Sun, Y.-Y.; Wiedmann, T.; Faturay, F.; Fry, J.; Gallego, B.; Geschke, A. Global socio-economic losses and environmental gains from the Coronavirus pandemic. *PLoS ONE* **2020**, *15*, e0235654. [CrossRef] [PubMed]
- World Health Organization. WHO Coronavirus (COVID-19) Dashboard. Available online: <https://covid19.who.int/> (accessed on 19 September 2022).
- Moore, S.; Hill, E.M.; Tildesley, M.J.; Dyson, L.; Keeling, M.J. Vaccination and non-pharmaceutical interventions for COVID-19: A mathematical modelling study. *Lancet Infect. Dis.* **2021**, *21*, 793–802. [CrossRef]
- Lang, R.; Atabati, O.; Oxoby, R.J.; Mourali, M.; Shaffer, B.; Sheikh, H.; Fullerton, M.M.; Tang, T.; Leigh, J.P.; Manns, B.J.; et al. Characterization of non-adopters of COVID-19 non-pharmaceutical interventions through a national cross-sectional survey to assess attitudes and behaviours. *Sci. Rep.* **2021**, *11*, 21751. [CrossRef]
- Ghazy, R.M.; Taha, S.H.N.; Elhadi, Y.A.M. Letter from Egypt. *Respirology* **2022**, *27*, 242–244. [CrossRef]
- Bo, Y.; Guo, C.; Lin, C.; Zeng, Y.; Li, H.B.; Zhang, Y.; Hossain, M.S.; Chan, J.W.M.; Yeung, D.W.; Kwok, K.O.; et al. Effectiveness of non-pharmaceutical interventions on COVID-19 transmission in 190 countries from 23 January to 13 April 2020. *Int. J. Infect. Dis.* **2021**, *102*, 247–253. [CrossRef]
- Galanis, G.; Di Guilmi, C.; Bennett, D.L.; Baskozos, G. The effectiveness of Non-pharmaceutical interventions in reducing the COVID-19 contagion in the UK, an observational and modelling study. *PLoS ONE* **2021**, *16*, e0260364. [CrossRef]
- World Health Organization. WHO Coronavirus (COVID-19) Dashboard. Available online: <https://covid19.who.int/?mapFilter=vaccinations> (accessed on 14 September 2022).
- Song, F.; Bachmann, M.O. Vaccination against COVID-19 and society's return to normality in England: A modelling study of impacts of different types of naturally acquired and vaccine-induced immunity. *BMJ Open* **2021**, *11*, e053507. [CrossRef]
- Bergwerk, M.; Gonen, T.; Lustig, Y.; Amit, S.; Lipsitch, M.; Cohen, C.; Mandelboim, M.; Levin, E.G.; Rubin, C.; Indenbaum, V. COVID-19 breakthrough infections in vaccinated health care workers. *N. Engl. J. Med.* **2021**, *385*, 1474–1484. [CrossRef]
- Kuhlmann, C.; Mayer, C.K.; Claassen, M.; Maponga, T.; Burgers, W.A.; Keeton, R.; Riou, C.; Sutherland, A.D.; Suliman, T.; Shaw, M.L. Breakthrough infections with SARS-CoV-2 omicron despite mRNA vaccine booster dose. *Lancet* **2022**, *399*, 625–626. [CrossRef]
- Alishaq, M.; Nafady-Hego, H.; Jeremijenko, A.; Al Ajmi, J.A.; Elgendy, M.; Vinoy, S.; Fareh, S.B.; Veronica Plaatjies, J.; Nooh, M.; Alanzi, N. Risk factors for breakthrough SARS-CoV-2 infection in vaccinated healthcare workers. *PLoS ONE* **2021**, *16*, e0258820. [CrossRef] [PubMed]
- Vicenti, I.; Basso, M.; Gatti, F.; Scaggiante, R.; Boccuto, A.; Zago, D.; Modolo, E.; Dragoni, F.; Parisi, S.G.; Zazzi, M. Faster decay of neutralizing antibodies in never infected than previously infected healthcare workers three months after the second BNT162b2 mRNA COVID-19 vaccine dose. *Int. J. Infect. Dis.* **2021**, *112*, 40–44. [CrossRef]
- Lucas, C.; Vogels, C.B.; Yildirim, I.; Rothman, J.E.; Lu, P.; Monteiro, V.; Gehlhausen, J.R.; Campbell, M.; Silva, J.; Tabachnikova, A. Impact of circulating SARS-CoV-2 variants on mRNA vaccine-induced immunity. *Nature* **2021**, *600*, 523–529. [CrossRef]
- Bar-On, Y.M.; Goldberg, Y.; Mandel, M.; Bodenheimer, O.; Freedman, L.; Kalkstein, N.; Mizrahi, B.; Alroy-Preis, S.; Ash, N.; Milo, R. Protection of BNT162b2 vaccine booster against COVID-19 in Israel. *N. Engl. J. Med.* **2021**, *385*, 1393–1400. [CrossRef] [PubMed]
- Choi, A.; Koch, M.; Wu, K.; Chu, L.; Ma, L.; Hill, A.; Nunna, N.; Huang, W.; Oestreicher, J.; Colpitts, T. Safety and immunogenicity of SARS-CoV-2 variant mRNA vaccine boosters in healthy adults: An interim analysis. *Nat. Med.* **2021**, *27*, 2025–2031. [CrossRef]
- Yue, L.; Zhou, J.; Zhou, Y.; Yang, X.; Xie, T.; Yang, M.; Zhao, H.; Zhao, Y.; Yang, T.; Li, H. Antibody response elicited by a third boost dose of inactivated SARS-CoV-2 vaccine can neutralize SARS-CoV-2 variants of concern. *Emerg. Microbes Infect.* **2021**, *10*, 2125–2127. [CrossRef]
- Goren, A.; Cadegiani, F.A.; Warmbier, C.G.; Vano-Galvan, S.; Tosti, A.; Shapiro, J.; Mesinkovska, N.A.; Ramos, P.M.; Sinclair, R.; Lupi, O. Androgenetic alopecia may be associated with weaker COVID-19 T-cell immune response: An insight into a potential COVID-19 vaccine booster. *Med. Hypotheses* **2021**, *146*, 110439. [CrossRef]
- Shmueli, L. Predicting intention to receive COVID-19 vaccine among the general population using the health belief model and the theory of planned behavior model. *BMC Public Health* **2021**, *21*, 804. [CrossRef]
- Sallam, M.; Al-Sanofi, M.; Sallam, M. A Global Map of COVID-19 Vaccine Acceptance Rates per Country: An Updated Concise Narrative Review. *J. Multidiscip. Healthc.* **2022**, *15*, 21–45. [CrossRef]
- Sallam, M. COVID-19 Vaccine Hesitancy Worldwide: A Concise Systematic Review of Vaccine Acceptance Rates. *Vaccines* **2021**, *9*, 160. [CrossRef] [PubMed]
- Fajar, J.K.; Sallam, M.; Soegiarto, G.; Sugiri, Y.J.; Anshory, M.; Wulandari, L.; Kosasih, S.A.P.; Ilmawan, M.; Kusnaeni, K.; Fikri, M.; et al. Global Prevalence and Potential Influencing Factors of COVID-19 Vaccination Hesitancy: A Meta-Analysis. *Vaccines* **2022**, *10*, 1356. [CrossRef] [PubMed]

25. ElSayed, D.A.; Bou Raad, E.; Bekhit, S.A.; Sallam, M.; Ibrahim, N.M.; Soliman, S.; Abdullah, R.; Farag, S.; Ghazy, R.M. Validation and Cultural Adaptation of the Parent Attitudes about Childhood Vaccines (PACV) Questionnaire in Arabic Language Widely Spoken in a Region with a High Prevalence of COVID-19 Vaccine Hesitancy. *Trop. Med. Infect. Dis.* **2022**, *7*, 234. [CrossRef] [PubMed]
26. MacDonald, N.E. Vaccine hesitancy: Definition, scope and determinants. *Vaccine* **2015**, *33*, 4161–4164. [CrossRef]
27. World Health Organization. Ten Threats to Global Health in 2019. Available online: <https://www.who.int/news-room/spotlight/ten-threats-to-global-health-in-2019> (accessed on 14 September 2022).
28. World Health Organization. Health Inequities in the Eastern Mediterranean Region: Selected Country Case Studies. Available online: <https://apps.who.int/iris/handle/10665/204666> (accessed on 16 September 2022).
29. Abdou, M.S.; Kheirallah, K.A.; Aly, M.O.; Ramadan, A.; Elhadi, Y.A.M.; Elbarazi, I.; Deghidy, E.A.; El Saeh, H.M.; Salem, K.M.; Ghazy, R.M. The coronavirus disease 2019 (COVID-19) vaccination psychological antecedent assessment using the Arabic 5c validated tool: An online survey in 13 Arab countries. *PLoS ONE* **2021**, *16*, e0260321. [CrossRef]
30. Rababa'h, A.; Abedalqader, N.; Ababneh, M. Jordanians' willingness to receive heterologous prime-boost COVID-19 vaccination and vaccine boosters. *Eur. Rev. Med. Pharmacol. Sci.* **2021**, *25*, 7516–7525.
31. Alobaidi, S.; Hashim, A. Predictors of the Third (Booster) Dose of COVID-19 Vaccine Intention among the Healthcare Workers in Saudi Arabia: An Online Cross-Sectional Survey. *Vaccines* **2022**, *10*, 987. [CrossRef]
32. Patwary, M.M.; Bardhan, M.; Disha, A.S.; Hasan, M.; Haque, M.Z.; Sultana, R.; Hossain, M.R.; Browning, M.H.E.M.; Alam, M.A.; Sallam, M. Determinants of COVID-19 Vaccine Acceptance among the Adult Population of Bangladesh Using the Health Belief Model and the Theory of Planned Behavior Model. *Vaccines* **2021**, *9*, 1393. [CrossRef]
33. Limbu, Y.B.; Gautam, R.K.; Pham, L. The Health Belief Model Applied to COVID-19 Vaccine Hesitancy: A Systematic Review. *Vaccines* **2022**, *10*, 973. [CrossRef]
34. Bandura, A.; Freeman, W.H.; Lightsey, R. Self-Efficacy: The Exercise of Control. *J. Cogn. Psychother.* **1999**, *13*. [CrossRef]
35. Al-Metwali, B.Z.; Al-Jumaili, A.A.; Al-Alag, Z.A.; Sorofman, B. Exploring the acceptance of COVID-19 vaccine among healthcare workers and general population using health belief model. *J. Eval. Clin. Pract.* **2021**, *27*, 1112–1122. [CrossRef]
36. Carpenter, C.J. A meta-analysis of the effectiveness of health belief model variables in predicting behavior. *Health Commun.* **2010**, *25*, 661–669. [CrossRef] [PubMed]
37. Abouzid, M.; Ahmed, A.A.; El-Sherif, D.M.; Alonazi, W.B.; Eatmann, A.I.; Alshehri, M.M.; Saleh, R.N.; Ahmed, M.H.; Aziz, I.A.; Abdelslam, A.E.; et al. Attitudes toward Receiving COVID-19 Booster Dose in the Middle East and North Africa (MENA) Region: A Cross-Sectional Study of 3041 Fully Vaccinated Participants. *Vaccines* **2022**, *10*, 1270. [CrossRef]
38. Lai, X.; Zhu, H.; Wang, J.; Huang, Y.; Jing, R.; Lyu, Y.; Zhang, H.; Feng, H.; Guo, J.; Fang, H. Public perceptions and acceptance of COVID-19 booster vaccination in China: A cross-sectional study. *Vaccines* **2021**, *9*, 1461. [CrossRef] [PubMed]
39. Qin, C.; Wang, R.; Tao, L.; Liu, M.; Liu, J. Acceptance of a third dose of COVID-19 vaccine and associated factors in China based on Health Belief Model: A national cross-sectional study. *Vaccines* **2022**, *10*, 89. [CrossRef] [PubMed]
40. Al-Qerem, W.; Al Bawab, A.Q.; Hammad, A.; Ling, J.; Alasmari, F. Willingness of the Jordanian population to receive a COVID-19 booster dose: A cross-sectional study. *Vaccines* **2022**, *10*, 410. [CrossRef]
41. Solis Arce, J.S.; Warren, S.S.; Meriggi, N.F.; Scacco, A.; McMurry, N.; Voors, M.; Syunyaev, G.; Malik, A.A.; Aboutajdine, S.; Adejo, O.; et al. COVID-19 vaccine acceptance and hesitancy in low- and middle-income countries. *Nat. Med.* **2021**, *27*, 1385–1394. [CrossRef]
42. Wang, H.; Huang, Y.-M.; Su, X.-Y.; Xiao, W.-J.; Si, M.-Y.; Wang, W.-J.; Gu, X.-F.; Ma, L.; Li, L.; Zhang, S.-K. Acceptance of the COVID-19 vaccine based on the health belief model: A multicenter national survey among medical care workers in China. *Hum. Vaccines Immunother.* **2022**, *18*, 2076523. [CrossRef]
43. Lin, Y.; Hu, Z.; Zhao, Q.; Alias, H.; Danaee, M.; Wong, L.P. Understanding COVID-19 vaccine demand and hesitancy: A nationwide online survey in China. *PLoS Negl. Trop. Dis.* **2020**, *14*, e0008961. [CrossRef]
44. Ai, J.; Zhang, Y.; Zhang, H.; Zhang, Q.; Fu, Z.; Lin, K.; Song, J.; Zhao, Y.; Fan, M.; Wang, H. Safety and immunogenicity of a third-dose homologous BBIBP-CorV boosting vaccination: Interim results from a prospective open-label study. *Emerg. Microbes Infect.* **2022**, *11*, 639–647. [CrossRef]
45. Ashmawy, R.; Hamdy, N.A.; Elhadi, Y.A.M.; Alqutub, S.T.; Esmail, O.F.; Abdou, M.S.M.; Reyad, O.A.; El-Ganainy, S.O.; Gad, B.K.; Nour El-Deen, A.E.-S. A Meta-Analysis on the Safety and Immunogenicity of COVID-19 vaccines. *J. Prim. Care Community Health* **2022**, *13*, 21501319221089255. [CrossRef] [PubMed]
46. Ghazy, R.M.; Ashmawy, R.; Hamdy, N.A.; Elhadi, Y.A.M.; Reyad, O.A.; Elmalawany, D.; Almaghraby, A.; Shaaban, R.; Taha, S.H.N. Efficacy and Effectiveness of SARS-CoV-2 Vaccines: A Systematic Review and Meta-Analysis. *Vaccines* **2022**, *10*, 350. [CrossRef] [PubMed]
47. Moawad, A.M.; Taha, S.H.N.; Ghazy, R.M.; Abdelhalim, W.A. Assessment of Self-Treatment Knowledge, Beliefs and Practice during COVID-19 Pandemic among Egyptian Population: A Cross-Sectional Study. *Egypt. J. Hosp. Med.* **2022**, *89*, 4516–4525.
48. Briand, S.C.; Cinelli, M.; Nguyen, T.; Lewis, R.; Prybylski, D.; Valensise, C.M.; Colizza, V.; Tozzi, A.E.; Perra, N.; Baronchelli, A.; et al. Infodemics: A new challenge for public health. *Cell* **2021**, *184*, 6010–6014. [CrossRef]
49. Shaaban, R.; Ghazy, R.M.; Elsherif, F.; Ali, N.; Yakoub, Y.; Aly, M.O.; ElMakhzangy, R.; Abdou, M.S.; McKinna, B.; Elzorkany, A.M.; et al. COVID-19 Vaccine Acceptance among Social Media Users: A Content Analysis, Multi-Continent Study. *Int. J. Environ. Res. Public Health* **2022**, *19*, 5737. [CrossRef]

50. Pacific, W.; Hasan, S.A.W. *Interim Statement on Booster Doses for COVID-19 Vaccination*; WHO: Geneva, Switzerland, 2021; Update.
51. Jairoun, A.A.; Al-Hemyari, S.S.; El-Dahiyat, F.; Jairoun, M.; Shahwan, M.; Al Ani, M.; Habeb, M.; Babar, Z.-U.-D. Assessing public knowledge, attitudes and determinants of third COVID-19 vaccine booster dose acceptance: Current scenario and future perspectives. *J. Pharm. Policy Pract.* **2022**, *15*, 26. [[CrossRef](#)]
52. Patwary, M.M.; Alam, M.A.; Bardhan, M.; Disha, A.S.; Haque, M.Z.; Billah, S.M.; Kabir, M.P.; Browning, M.H.; Rahman, M.M.; Parsa, A.D. COVID-19 Vaccine Acceptance among Low-and Lower-Middle-Income Countries: A Rapid Systematic Review and Meta-Analysis. *Vaccines* **2022**, *10*, 427. [[CrossRef](#)]
53. Wang, R.; Zhang, Q.; Ge, J.; Ren, W.; Zhang, R.; Lan, J.; Ju, B.; Su, B.; Yu, F.; Chen, P. Analysis of SARS-CoV-2 variant mutations reveals neutralization escape mechanisms and the ability to use ACE2 receptors from additional species. *Immunity* **2021**, *54*, 1611–1621.e5. [[CrossRef](#)]
54. Eysenbach, G.; Wyatt, J. Using the Internet for surveys and health research. *J. Med. Internet Res.* **2002**, *4*, e862. [[CrossRef](#)]