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COVID-19 Vaccine Distribution Patterns for Prioritized Age Group: Analysis of European Nations

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Abstract

The emergence of the SARS-CoV-2 virus resulted in a health and economic crisis worldwide. Although everyone is susceptible to COVID-19, the elderly have compromised immune systems and often suffer from chronic underlying diseases, which makes them more vulnerable. This study aims to assess variation in COVID-19 vaccine distribution patterns across different age groups in European countries and to understand the extent to which European countries have prioritized vulnerable age groups (age > 70) in their vaccination programs. The study utilized open data from the European Center for Disease Prevention and Control (ECDC) and employed an observational, retrospective study design to examine the distribution of the COVID-19 vaccine among various age groups in several European countries from September 2021 to September 2023. Results reveal that vaccination rates increase with age, peaking at the 25 - 49 age group (1.34×10^{-4}), after which there was a decline in vaccination rate. Analysis of variance (ANOVA) was used to investigate the equality of vaccination rates across the 29 countries in Europe, which resulted in a p-value of <0.05 for both sources of variation (age group interval and countries). This study shows a low coverage of COVID-19 vaccination for the prioritized age group (>70) during the study period as no country achieved the 70% coverage aimed by WHO. Continuous efforts must be made to ensure larger coverage of COVID-19 vaccination among this vulnerable population in order to protect them from severe outcomes in this region.

Keywords

SARS-CoV-2, COVID-19, Vaccines, Prioritized Age Group, European Nations

1. Introduction

The emergence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) resulted in a health and economic crisis worldwide [1] [2]. Infections reported as of September 15, 2024, are over 776 million, with about 7.1 million deaths [3]. The unprecedented speed of COVID-19 vaccine development in record time illustrated that, when required, collaborative efforts by governments, funders, regulators, and manufacturers could dramatically accelerate vaccine development [4]. These vaccines have proven to have high efficacy in reducing the risk of severe illness, hospitalization, and mortality. Furthermore, vaccines offer appreciable protection against new variants and aid in a reduction in transmission due to the reduced risk of infection and further transmission to others [5] [6]. Although COVID-19 poses a risk to individuals across all age groups, older adults are more susceptible as a result of compromised immune systems and frequently suffer from chronic underlying diseases. Infections in this population tend to spread quickly, culminating in severe outcomes. As a result, the elderly and those with chronic health concerns are at a considerably increased risk of being hospitalized or dying from COVID-19 [7]. During the height of the pandemic, there was a significant focus on equity. However, WHO provided the overarching principles, objectives, and activities necessary for countries to develop plans for vaccine rollout. Aiming for 100% coverage of a complete COVID-19 vaccine series among all at-risk populations, including older adults, the strategy brief was updated in July 2022 [7] [8]. Children and adolescents had more favorable outcomes and milder clinical manifestations than adults, even in the midst of the global epidemic. Some children, meanwhile, experienced severe clinical manifestations and even passed away [9]-[11]. Prioritizing vaccines can be done in two major ways: 1) by directly vaccinating individuals who are most at risk of severe consequences, and 2) by indirectly protecting them by vaccinating those who spread the disease the most. Given their crucial role in transmission, model-based analyses of the key trade-offs involved in the different approaches to influenza vaccination have supported the policy of vaccinating children [1] [12].

More than a year after the World Health Organization announced COVID-19 a public health emergency of worldwide significance, Europe continues to struggle with it [13]. For example, as of May 2023, the cumulative cases in just France, Germany, Italy, and Russia have reached 127 million, with active infections totaling 504,179 and total deaths nearing one million [14]. However, significant attempts were made to use every available resource to mitigate the impacts of COVID-19 that resulted in increased mental health concerns and risk of complications for pre-existing diseases for both young and the elderly [15]. Such efforts by the European Commission at ensuring equitable access to COVID-19 vaccines to the public and supporting vaccination campaigns in partner countries were through online platforms such as developed mobile applications to provide easy access to vaccination information and schedules [16]. However, outcomes varied substantially across countries. An analysis of official data from the European Center for Disease Prevention and Control (ECDC) reveals considerable variation in vaccination rates among EU countries [17]-[19]. A study [20], revealed accessibility to COVID-19 vaccines increased with age. Given the significance of prioritizing the elderly who are often part of the vulnerable populations, our study aims to evaluate the age-specific COVID-19 vaccine distribution patterns in twenty-nine (29) European Union (EU) countries to better understand how COVID-19 vaccine distribution patterns vary across different age groups in European countries, identify the variation that influences the age-specific vaccination strategies among European nations and to understand the extent European countries have prioritized vulnerable age groups (Age > 70) in their vaccination programs.

2. Study Design and Methodology

2.1. Study Design

This study adopts a retrospective, observational design that leverages secondary data to analyze age-specific COVID-19 vaccine distribution patterns across multiple European nations. The aim is to explore how vaccines were distributed across various age groups, and countries, over the study period of September 2021 to September 2023.

Given that this study uses pre-existing aggregated data, no direct interventions or modifications are made to the data. The analysis will focus on observing trends and drawing conclusions from the distribution patterns. A cross-sectional approach will be used at multiple time points to capture shifts in distribution patterns as the pandemic progressed and vaccine supply increased.

This design is appropriate for assessing vaccine distribution policies retrospectively, allowing for a detailed examination of trends without the need for primary data collection. The key advantage of using secondary data is its ability to capture wide-ranging and large-scale data points across different time periods and geographic regions, which provides a robust framework for analyzing population-level patterns.

2.2. Data Source

The study will utilize publicly available data obtained from the European Centre for Disease Prevention and Control (ECDC). The ECDC compiles and shares data on COVID-19 vaccination coverage across European countries. This data will serve as the backbone of the cross-country comparison.

Data collection for this study was submitted to the European Union/European Economic Area through the European Surveillance System (TESSy) and covered the period from September 2021 to September 2023. To ensure uniformity across countries, the study will limit its scope to countries with complete, reliable data on vaccine doses administered by age group. The study will include variables such as age, number of doses administered, and the time period of administration.

2.3. Study Population

The study population is composed of aggregated, age-specific vaccine data representing individuals from multiple European countries. This population-level data includes individuals who received one or more doses of a COVID-19 vaccine during the study period. Since the study utilizes secondary data, no personal identifiers will be involved, and the analysis will focus on aggregate outcomes at the national level. These age categories allow for a detailed examination of vaccine distribution across various demographic segments, facilitating comparisons between younger and older populations. The choice of countries will be based on the availability of comprehensive data for these age groups.

2.4. Variables

The analysis will focus on several key variables, both dependent and independent, to ensure a thorough examination of vaccine distribution patterns:

- Number of people that received the first dose.
- Number of vaccine doses administered: This will be the primary outcome measure, representing the total number of doses administered to individuals in each age group across the selected countries. This variable will be categorized by age group, and country to allow for detailed cross-sectional.
- Age group: Age-specific categories will serve as a primary independent variable, enabling comparisons between different demographic segments and their access to vaccines.
- Country: The countries included in the study will serve as an independent variable, allowing for cross-country comparisons in vaccine distribution patterns. Countries will be selected based on the availability and completeness of data. The countries considered in the study are namely: AT (Austria), BE (Belgium), BG (Bulgaria), CY (Cyprus), CZ (Czech), DK (Denmark), EE (Estonia), EL (Greece), ES (Spain), FI (Finland), FR (France), HR (Croatia), HU (Hungary), IE (Ireland), IS (Iceland), IT (Italy), LI (Liechtenstein), LT (Lithuania), LU (Luxembourg), LV (Latvia), MT (Malta), NL (Netherlands), NO (Norway), PL (Poland), PT (Portugal), RO (Romania), SE (Sweden), SI (Slovenia), and SK (Slovakia).

2.5. Data Analysis

The analysis was conducted using both descriptive and inferential statistical methods. The following steps outline the process for analyzing the dataset.

2.5.1. Descriptive Analysis

The initial analysis will involve calculating summary statistics for some variable frequencies, to provide a clear overview of vaccine distribution across age groups and countries. These results will help identify overarching patterns in the data, including which age groups received higher priority in the vaccine distribution process.

2.5.2. Comparative Analysis

To determine whether there are significant differences in vaccine distribution between age groups and countries, the following inferential statistical tests will be applied:

1) Analysis of Variance (ANOVA) will be used to compare mean vaccination rates, between different age groups across the countries. This will help assess whether certain age groups received disproportionately more vaccines across different countries.

2) The Z-tests will be employed to compare the proportion of vaccinated individuals in high priority age groups (>70 years) across selected countries.

2.5.3. Cross-Country Comparisons

To explore cross-country differences in vaccine distribution strategies, cross-tabulation and chi-square tests were used. This will allow the study to assess whether certain countries prioritized older age groups more than others. Graphical representations such as heat maps and bar charts will visually display the distribution patterns. For example, countries with a high proportion of elderly citizens might have prioritized vaccines for the 60+ age groups, while others may have opted for a more even distribution across all age groups.

2.5.4. Software and Tools

The data will be processed and analyzed using R programming Language. This language is well-equipped to handle large datasets and conduct the variety of statistical tests outlined above. The graphical outputs, including plots, heat maps, and comparative bar charts, will be generated using these tools to provide a clear and comprehensive visual representation of the findings.

2.6. Ethical Considerations

Since this study uses secondary data that is publicly available and anonymized at the aggregate level, there are minimal ethical concerns regarding individual privacy. However, all data will be handled in accordance with ethical guidelines for the use of secondary data, ensuring that no attempts are made to de-anonymize or link the data to specific individuals. Additionally, the study will comply with all legal and institutional policies regarding the use of publicly available data.

2.7. Data Description

The study uses pre-existing aggregated data that were submitted by European Union/European Economic Area (EU/EEA) countries to ECDC through The European Surveillance System (TESSy) on scheduled dates. EU/EEA countries report aggregated data on the number of individuals receiving one vaccine dose during the reporting period starting from 01 September 2023. Doses are also reported by vaccine product. The variables in the dataset are summarized in the Appendix 1 titled data dictionary.

3. Results

3.1. Age Distribution of Population

In this study, we focused primarily on the non-overlapping age groups 0 - 4, 5 - 9, 10 - 17, 18 - 24, 25 - 49, 50 - 69 and >70 (Prioritized Group) as shown in Figure 1. Health Care Workers (HCW), Pregnant Women and other individuals aged 18 - 59 with underlying chronic medical conditions were excluded in the study.

Age	Total Vaccinated
Age 0-4	20,624
Age 5-9	2,979,509
Age 10-17	11,428,301
Age 18-24	30,369,968
Age 25-49	129,017,491
Age 50-59	57,520,817
Age 60-69	53,257,068
Age >70	63,209,649

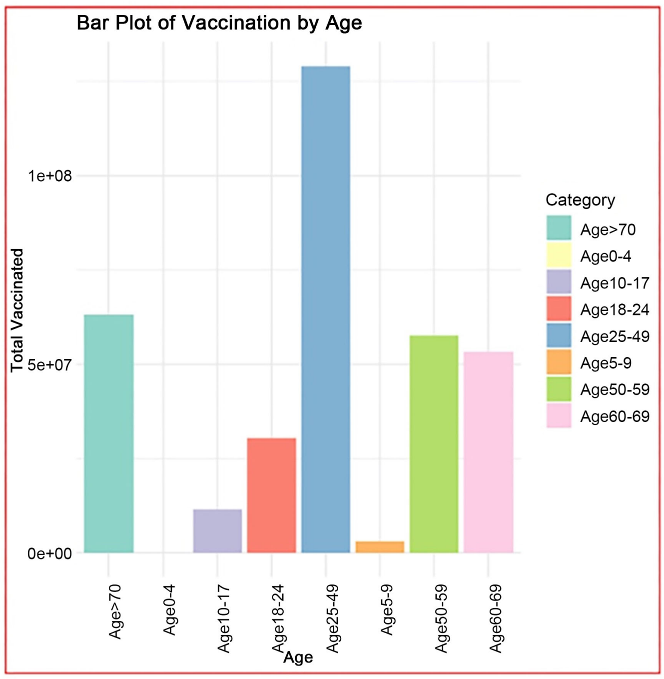

Figure 1. Bar Plot showing the graphical display of vaccination by country.

3.2. Chi-Square Test of Association between Age Groups and Countries

We test for association between age groups and countries. The goal is to verify if the countries in the study jointly prioritized certain age groups against others in their vaccination campaign. Using the Chi-Square test of association, we present the test below:

Null hypothesis (H_0): There is no association between age groups and countries in the vaccination campaign.

Alternative hypothesis (H_1): There is an association between age groups and countries in the vaccination campaign.

Level of significance = 5%

Test Statistic: $\chi^2 = \Sigma_{ij} \frac{\left(O_{ij} - E_{ij}\right)^2}{E_{ij}}$ follows $\chi_{(r-1)(c-1)}$

where

O_{ij} = Observed values;

E_{ij} = Expected Values;

$(r-1)(c-1)$ = Degree of freedom.

Decision Rule:

Reject the null hypothesis if the p-value is less than 0.05. Do not reject if otherwise.

It is important to note that, vaccine frequency distribution by itself does not tell the whole story because, it only captures frequency and not rates. Therefore, a contingency table of age groups and countries to investigate association between the two categorical variables namely age groups and country using Chi-Square test was used as presented in Table 1. The result shows a p-value (2.2e−16) < 0.05, we therefore, conclude that vaccination in different countries in Europe is associated with the age intervals.

Table 1. Chi-square result.

Chi-Square	Degree of freedom	p-value
39,166	196	2.2e−16

3.3. Age Vaccination Rates across the Countries

Table 2 shows, vaccination rates increase with age, peaking at the 25 - 49 age group (1.34×10^{-4}), after which, there was a decline in vaccination rate. The youngest age group (0 - 4 years) has the lowest rate (3.04×10^{-8}), while older adults, especially those over 50, show moderate rates. There is a notable rise from childhood (0 - 17 years) to young adulthood (18 - 24 years). The rates remain relatively stable between 50 and 69 years, with a slight drop in those over 70. This pattern suggests higher vaccination uptake among working-age adults, followed by a decline in older age groups.

Table 2. Showing vaccination rates across countries.

Age	Vaccination Rates	Age	Vaccination Rates
Age 0 - 4	3.04e−08	Age 25 - 49	1.34e−04
Age 5 - 9	4.18e−06	Age 50 - 59	5.83e−05
Age 10 - 17	9.18e−06	Age 60 - 69	5.45e−05
Age 18 - 24	3.08e−05	Age > 70	3.21e−05

3.4. Comparison of Vaccination Rates across European Countries

In **Table 3**, we performed an analysis of variance (ANOVA) to investigate the equality of mean vaccination rates across the 29 countries in Europe. Since our p-values for both sources of variations (age groups interval and countries) are <0.05, We conclude that there are significant differences in age-specific vaccination rates. Secondly, the results show a significant difference in vaccination rates across the countries as displayed in **Figure 2**. Also, the very low p-values coming from the variables indicate that the effects of the age and country are highly significant statistically. We utilized the Tukey Honest Significant Difference (HSD) to identify the pairs that are statistically significant at 5% level. The results in (**Table 4**) showed that most of the pairwise comparisons were statistically significant with p-value < 0.05. Hence to reduce ambiguity, we identified the age groups that actually did not lead to the variation.

Table 3. Showing comparison of vaccination rates across European countries using ANOVA.

Source of Variation	D.f.	Sum Sq.	Mean Sq.	F-value	p-value
Age	7	1.962e+11	2.803e+10	232.2	2.2e−16***
Country	28	1.201e+12	4.289e+10	355.3	2.2e−16***
Residuals	593432	7.164e+13	1.207e+08		

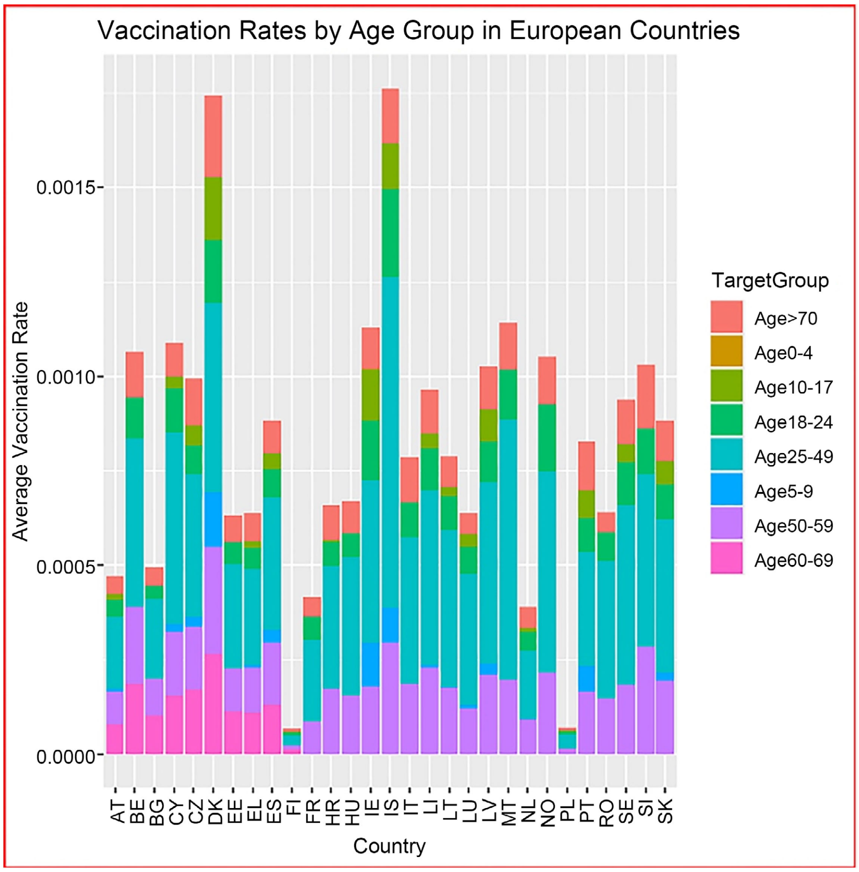

Figure 2. Showing vaccination rates by Age group in European countries.

Table 4. Tukey multiple comparisons of mean vaccination rates for pairs that not statistically significant at 5% level.

Age	Diff	CI (L)	CI (U)	Adj. p-value
Age 18 - 24-Age > 70	−27.432	−189.481	134.618	0.996
Age 10 - 17-Age 0 - 4	−105.691	74.034	285.416	0.632
Age 5 - 9-Age 0 - 4	56.509	−151.313	264.331	0.992
Age 5 - 9-Age 10 - 17	−49.182	−226.606	128.242	0.991
Age 60 - 69-Age 50 - 59	−75.338	−260.574	109.898	0.922

3.5. Comparisons of Mean Vaccination Rates for Pairs That Not Statistically Significant at 5% Level

We performed a series of Z-tests, presented in the table below, Table 5, which compares vaccination proportions in the high-priority age group-in people over 70-years-old across different countries. There was a significant difference between vaccination proportion in Austria-20% and Belgium-33%: $\chi^2 = 298.82$, $p < 2.2e{-}16$; and between Denmark-20% and Iceland-33%: $\chi^2 = 6.23$, $p < 0.013$. A repeated comparison between Denmark and Iceland ($p < 0.0125$) reaffirmed the significant disparity. Additionally, Romania (33%) and Sweden (29%) showed a statistically significant difference in vaccination coverage ($\chi^2 = 17.95$, $p < 2.27e{-}05$). The insignificant difference in vaccination proportion between Finland and Poland suggests a similarity in proportions, probably because of similar policy regimes addressing this group. The summary of the vaccination coverage for the > 70 years age group is presented in Table 6. Belgium, Bulgaria, Italy, Estonia, Romania, France, and Malta generally have the highest vaccination proportion (33.3%). Conversely, Austria reports the lowest proportion at 10.6%, while several countries, including Greece, Spain, Finland, Croatia, Lithuania, the Netherlands, and Poland, have around 20% vaccination coverage for the priority group.

3.6. Comparison of Vaccination Proportion in High-Priority Age Group (Age > 70) across Some Selected Countries

Table 5. Showing a comparison of vaccination proportion in high-priority age group (Age > 70) across some selected countries.

Hypothesis	χ^2 value	df	Sample Estimates	p-value
Ho: $p_{AT} = p_{BE}$ H1: $p_{AT} \neq p_{BE}$	298.82	1	$p_{AT} = 0.200$ $p_{BE} = 0.333$	2.2e-16
Ho: $p_{DK} = p_{IS}$ H1: $p_{AT} \neq p_{IS}$	6.234	1	$P_{DK} = 0.200$ $p_{IS} = 0.333$	0.013
Ho: $p_{DK} = p_{IS}$ H1: $p_{DK} \neq p_{IS}$	6.231	1	$p_{Dk} = 0.228$ $p_{IS} = 0.203$	0.012
Ho: $p_{RO} = p_{SE}$ H1: $p_{RO} \neq p_{SE}$	17.952	1	$p_{RO} = 0.3333$ $p_{SE} = 0.2857$	2.27e−05

Table 6. Showing a percentage of age > 70 vaccinated in each country across Europe.

Country	% Age > 70 Vaccinated	Country	% Age > 70 Vaccinated	Country	% Age > 70 Vaccinated
AT	10.6%	DK	22.8%	FR	33.3%
BE	33.3%	EE	33.3%	HR	20.0%
BG	33.3%	EL	20.0%	HU	33.3%
CY	24.2%	ES	20.0%	IE	26.4%
CZ	24.1%	FI	20.0%	IS	20.3%
IT	33.3%	NL	20.0%	SI	30.5%
LI	22.2%	NO	31.7%	SK	23.3%
LT	20.0%	PL	20.0%	MT	33.3%
LU	22.2%	PT	20.3%	SE	28.6%
LV	25.9%	RO	33.3%		

4. Discussion, Conclusion and Recommendations

4.1. Discussion

Despite the improved supply of COVID-19 vaccine in 2021, which was meant to lead to improved and larger coverage for Europeans countries and the vulnerable populations such as the elderly which in our study were the prioritized age group (>70 years), there was a low vaccination coverage of this age group. Our study evaluated age-specific COVID-19 vaccine distribution patterns in (29) European Union (EU) countries to better understand the variation in the distribution patterns across different age groups and to access the level of prioritization given to prioritized vulnerable age groups (Age > 70) in their vaccination programs. Our result shows that vaccination rates in countries in Europe are associated with the age intervals. Two sources of variations in our study were Age and Country. A critical examination of the ANOVA result suggests country is a stronger source of variation than age in vaccination rates and frequencies across the continent. This observation is evident in the F-value of Country (355.3) which is much greater than F-value of Age (232.2). Hence, we can conclude that geographical or other conditions peculiar to the country are more influential in driving the outcome than the age itself. There was a concerning low coverage of vaccination for the >70 years age group across Europe, with seven (7) countries namely Belgium, Bulgaria, Italy, Estonia, Romania, France, and Malta vaccinated just about 1:3 population (33.3%) of their most vulnerable age-group population given the risk of severe outcomes that were associated with this age group. Conversely, Austria reports the lowest rate at 10.6%, while several countries, including Greece, Spain, Finland, Croatia, Lithuania, the Netherlands, and Poland, have around 20% vaccination coverage for the priority group. Given that morbidity and mortality are highest among this age group [7] [21], based on data, no European country achieved the 70% coverage aimed by WHO by 2022 within the time period [22]. Contrary to the low coverage among European countries, by early April 2021, 79.6% of adults aged 65 - 74 and 78.3% of ≥75 years had received at least ≥1 dose of vaccine in the US [23]. Approximately 99.9% of older persons aged 65 - 74 and 98.1% of those aged ≥ 75 had received at least one dose of a COVID-19 vaccine, by 2022. In the United Kingdom, around 95% of those aged ≥ 65 have been fully vaccinated against COVID-19 [24] [25]. In other studies, even the oldest-old age group (≥80 years) had 72.0% of the population vaccinated with the first dose by the end of summer 2022 [26].

Our study shows there was a low coverage of COVID-19 vaccination for the prioritized age group (>70) during the study period. Challenges such as vaccines hesitancy, poor public health outreach to the elderly group and logistical constraint may have independently or collectively contributed to the low coverage. This supports the findings of Zhang *et al.*, that living alone, being older, having chronic conditions, and having a lower self-rated health status were all associated with vaccine resistance and hesitation, and they concluded that poor health or vaccine side effects were the main causes [27]. Additionally, the elderly may not have internet access, are inexperienced with online scheduling, or lack transportation means. These factors pose a challenge to easy access to vaccines [28].

Continuous efforts must be made to ensure larger coverage of COVID-19 vaccination among this vulnerable population in other to protect them from additional severe outcomes of COVID-19 among the European countries. Primary healthcare centers should integrate Covid-19 vaccination into regular immunization services to ensure wider coverage of vaccination for all age groups and most importantly, the vulnerable age population.

4.2. Conclusion

Our study highlights a significant gap in COVID-19 vaccine coverage for the prioritized elderly population (age > 70) across 29 European Union countries, despite improved vaccine supply in 2021. The findings indicate that variations in vaccination rates are influenced more by country-specific factors than by age, as evidenced by the higher F-value for the country in the ANOVA analysis. The low vaccination coverage in several countries, particularly among the most vulnerable age groups, underscores the need for targeted interventions. Factors such as vaccine hesitancy, inadequate public health outreach to elderly populations, and logistical challenges may have contributed to this shortfall. In contrast, countries like the United States and the United Kingdom demonstrated significantly higher coverage among older adults. To protect this high-risk population from severe outcomes of COVID-19, continuous efforts are necessary to improve vaccine distribution and uptake. Integrating COVID-19 vaccination into routine immunization services at primary healthcare centers could help ensure broader coverage, particularly for vulnerable populations. Addressing the gaps identified in this study is crucial to achieving equitable vaccine access and reducing the impact of COVID-19 among older adults in Europe.

4.3. Recommendations

To improve COVID-19 vaccination coverage among the elderly, potential measures that can be taken to improve vaccine distribution includes:

1) Strengthening public health communication strategies is crucial to addressing vaccine hesitancy and misinformation in this vulnerable group.

2) Expanding access through mobile units, home-based services, and simplifying administrative processes could overcome logistical barriers, especially in rural areas.

3) Integrating COVID-19 vaccination into routine healthcare services at primary care centers would ensure sustained coverage for older adults.

4) Given the significant variation in vaccination rates between countries, national strategies should be adapted to address country-specific challenges such as supply chain issues, public health infrastructure, and cultural factors.

5) Enhancing international collaboration, knowledge exchange, and continuous monitoring of vaccine supplies are also critical to ensuring equitable access.

Future research should focus on understanding the specific determinants of vaccine hesitancy among older adults, particularly in the context of socio-cultural and psychological barriers. Further investigation is needed into the effectiveness of logistical interventions like mobile vaccination units in reaching rural and underserved populations. Additionally, studies could explore how country-specific factors such as healthcare systems and political environments influence vaccine distribution success. Longitudinal research examining the integration of COVID-19 vaccines into routine immunization programs and its impact on coverage rates would offer valuable insights for future pandemic preparedness. Lastly, examining the public health consequences of low vaccine coverage among the elderly in terms of morbidity and mortality could inform better strategies for prioritizing high-risk populations in future health crises.

Author Contributions

Conceptualization: O.E; V.O; F.O; and J.J, Methodology: O.E; J.S; and P.T.; Writing the manuscript: V.O., J.J., C.A., W.A. and A.A, Data curation: O.E; J.S; and P.T. Review and Editing: R.A; F.O; Visualization: R.A; O.E; and P.T.; All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement

Not applicable.

Data Availability Statement

Data are contained within the article.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendices

Appendix 1. Data Dictionary

Variable	Definition	Code
YearWeekISO	Date when the vaccine was received/administered.	yyyy-MM
ReportingCountry	ISO 3166-1-alpha-2	two-letter code
Denominator	Denominators reported by countries for TargetGroup = "HCW", "Pregnant" and "Chronic".	Numeric
NumberOfIndivOneDose	Number of individuals vaccinated with one dose of the COVID_19 vaccine during each reporting period from 01 September 2023 onwards.	Numeric
Region	As a minimum data should be reported at national level (Region = country code).	Country/NUTS1 or 2/GAUL1/Country specific
TargetGroup	Target group for vaccination.	Age 60 - 69 = 60 years to 69 years Age 70 - 79 = 70 years to 79 years Age 80+ = 80 years and over Age 60+ = 60 years and over Age UNK = Unknown age ALL = Individuals aged 18+ HCW = Health care workers Chronic = Adults aged between 18 and 59 years with chronic conditions Pregnant = Pregnant women
Vaccine name	Name of vaccine.	BIMER = Hipra - Bimervax COMXBB = Pfizer BioNTech – Comirnaty Omicron XBB.1.5 MODXBB = Moderna - Spikevax XBB.1.5 NVXDXBB = Novavax – Nuvaxovid XBB.1.5 OTHER = Other vaccine products
Population	Overall country population obtained from Eurostat/UN	Numeric

Source: European Centre for Disease Control (ECDC).

Appendix 2. Table Showing Age-Country Comparison

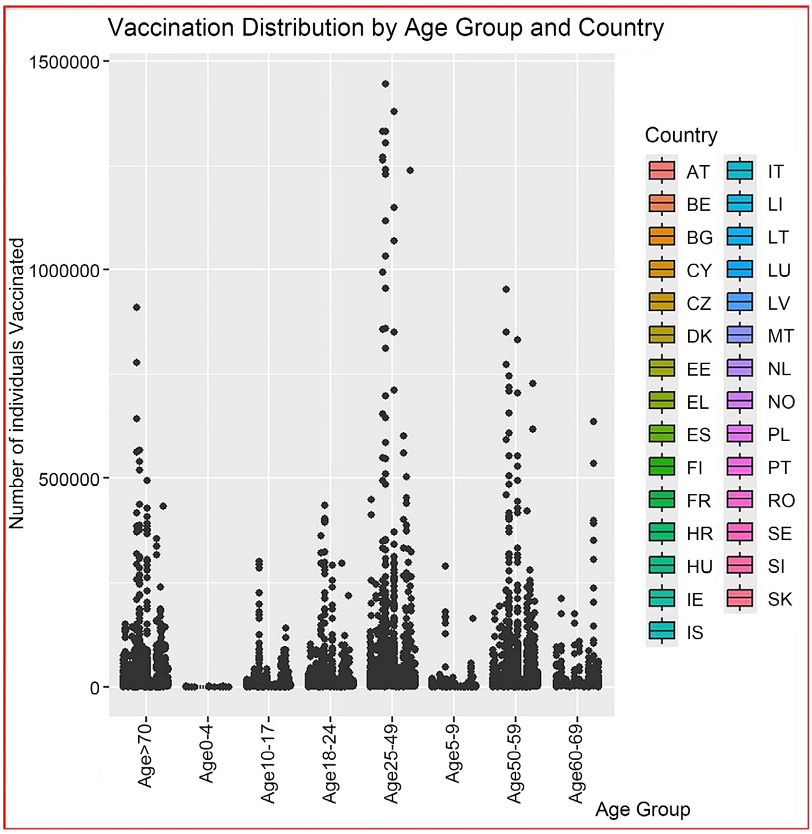
age_country_table

	AT	BE	BG	CY	CZ	DK	EE	EL	ES	FI
Age >70	1525	1242	1104	1258	1051	699	1698	2030	1728	62640
Age0_4	1441	0	0	78	45	23	0	1015	864	31320
Age10_17	2882	0	0	1125	695	379	0	2030	1728	62640
Age18_24	1441	621	552	624	595	453	849	1015	864	31320
Age25_49	1441	621	552	630	659	537	849	1015	864	31320
Age5_9	1441	0	0	226	116	88	0	1015	864	31320
Age50_59	1728	621	552	628	608	458	849	1015	864	31320
Age60_69	2511	621	552	630	588	425	849	1015	864	31320

	FR	HR	HU	IE	IS	IT	LI	LT	LU	LV
Age >70	5320	1236	1338	1120	720	1428	1014	1308	1746	960
Age0_4	0	618	0	40	348	0	0	654	0	15
Age10_17	0	1236	0	496	696	0	1014	1308	1746	508
Age18_24	2660	618	669	501	360	714	507	654	873	490
Age25_49	2660	618	669	741	360	714	507	654	873	575
Age5_9	0	618	0	108	348	0	507	654	873	87
Age50_59	2660	618	669	613	360	714	507	654	873	534
Age60_69	2660	618	669	629	360	714	507	654	873	535

	MT	NL	NO	PL	PT	RO	SE	SI	SK
Age >70	1088	2610	987	24650	1334	976	1160	656	713
Age0_4	0	1305	0	12325	248	0	0	0	53
Age10_17	0	2610	0	24650	1013	0	580	0	376
Age18_24	544	1305	454	12325	837	488	580	335	437
Age25_49	544	1305	571	12325	1090	488	580	440	514
Age5_9	0	1305	0	12325	360	0	0	0	92
Age50_59	544	1305	538	12325	830	488	580	376	454
Age60_69	544	1305	542	12325	847	488	580	345	422

Appendix 3. Scatter Plot of Vaccination Distribution by Age Group and Country



Appendix 4

Tukey multiple comparisons of means of vaccination rates by Age
95% family-wise confidence level

	diff	lwr	upr	p adj
Age0_4-Age >70	-503.90023	-679.5510	-328.2494	0.0000000
Age10_17-Age >70	-398.20897	-536.5657	-259.8523	0.0000000
Age18_24-Age >70	-27.43162	-189.4807	134.6175	0.9996018
Age25_49-Age >70	1489.28545	1328.0945	1650.4764	0.0000000
Age5_9-Age >70	-447.39108	-620.6866	-274.0955	0.0000000
Age50_59-Age >70	390.46870	228.9218	552.0156	0.0000000
Age60_69-Age >70	315.13086	154.1658	476.0959	0.0000001
Age10_17-Age0_4	105.69127	-74.0337	285.4162	0.6321549
Age18_24-Age0_4	476.46861	277.9279	675.0093	0.0000000
Age25_49-Age0_4	1993.18568	1795.3448	2191.0265	0.0000000
Age5_9-Age0_4	56.50916	-151.3125	264.3308	0.9918115
Age50_59-Age0_4	894.36894	696.2380	1092.4999	0.0000000
Age60_69-Age0_4	819.03109	621.3742	1016.6879	0.0000000
Age18_24-Age10_17	370.77735	204.3208	537.2339	0.0000000
Age25_49-Age10_17	1887.49442	1721.8732	2053.1156	0.0000000
Age5_9-Age10_17	-49.18211	-226.6059	128.2417	0.9908016
Age50_59-Age10_17	788.67767	622.7100	954.6453	0.0000000
Age60_69-Age10_17	713.33983	547.9385	878.7412	0.0000000
Age25_49-Age18_24	1516.71707	1330.8469	1702.5872	0.0000000
Age5_9-Age18_24	-419.95945	-616.4195	-223.4994	0.0000000
Age50_59-Age18_24	417.90032	231.7214	604.0792	0.0000000
Age60_69-Age18_24	342.56248	156.8882	528.2368	0.0000006
Age5_9-Age25_49	-1936.67652	-2132.4293	-1740.9238	0.0000000
Age50_59-Age25_49	-1098.81675	-1284.2492	-913.3843	0.0000000
Age60_69-Age25_49	-1174.15459	-1359.0804	-989.2288	0.0000000
Age50_59-Age5_9	837.85978	641.8138	1033.9058	0.0000000
Age60_69-Age5_9	762.52193	566.9551	958.0887	0.0000000
Age60_69-Age50_59	-75.33784	-260.5740	109.8983	0.9223420