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Impact of Lifting Mask Mandates on COVID-19 Incidence and Mortality in Portugal: An Ecological Study

Impacto do Fim da Obrigatoriedade do Uso de Máscara em Portugal na Incidência e Mortalidade de COVID-19: Um Estudo Ecológico

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ABSTRACT

Introduction: The use of face masks in public was one of several COVID-19 non-pharmaceutical interventions adopted to mitigate the pandemic in Portugal. The aim of this study was to evaluate the impact of lifting the mask mandate on the April 22, 2022 on COVID-19 incidence and mortality in mainland Portugal and in the Azores. As a secondary objective, we aimed to evaluate the evolution of COVID-19 cases in a setting without a mask mandate (Azores islands) and in a setting with a mask mandate (Madeira islands).

Methods: Surveillance data on laboratory-confirmed COVID-19 cases and COVID-19 deaths were used to conduct an interrupted time series analysis to estimate changes in daily incidence and deaths during a mask mandate period (28th March – 21st April 2022) and during a post-mask mandate period (22nd April – 15th May 2022), in mainland Portugal and Azores. In a second phase, for each archipelago, we fitted a negative binomial regression model, with daily COVID-19 incident cases as the primary outcome of interest, and relative frequency of Omicron BA.5 lineage as explanatory variable.

Results: Significant changes in trends were observed for the overall incidence rate and COVID-19 deaths; increasing trends were observed for COVID-19 incidence and deaths in the post mandate period [5.3% per day; incidence rate ratio (IRR): 1.053; 95% confidence interval (CI): 1.029 - 1.078] and [3.2% per day; mortality rate ratio (MRR): 1.032; 95% CI: 1.003 - 1.062], respectively. For every unit increase in the percentage of Omicron BA.5 lineage there was a 1.5% increase per day (IRR: 1.015; 95% CI: 1.006 - 1.024) in COVID-19 incidence rate in the Azores islands, while for Madeira islands an increase of 0.05% COVID-19 cases per day was observed (IRR: 1.005; 95% CI: 1.000 - 1.010).

Conclusion: Lifting the mask mandate in Portugal was associated with an increase in COVID-19 incidence and deaths, thus highlighting the positive effect of face mask policies in preventing respiratory virus transmission and saving lives.

Keywords: COVID-19; Masks; Pandemics; Portugal; SARS-CoV-2

RESUMO

Introdução: O uso de máscara em público foi uma das várias intervenções não farmacêuticas adotadas para mitigar a pandemia de COVID-19 em Portugal. Pretendeu-se com este estudo avaliar o impacto do levantamento da obrigatoriedade do uso de máscara, a 22 de abril de 2022, na incidência e mortalidade por COVID-19, em Portugal Continental e nos Açores. Como objetivo secundário, pretendeu-se avaliar a evolução de casos de COVID-19 numa região sem obrigatoriedade de uso de máscara (Região Autónoma dos Açores) e numa região com obrigatoriedade de uso de máscara (Região Autónoma da Madeira).

Métodos: O número de casos de COVID-19 confirmados laboratorialmente e de mortes específicas por COVID-19 foram utilizados para realizar uma análise de séries temporais interrompidas, de modo a estimar mudanças na incidência diária e óbitos, durante um período com obrigatoriedade de uso de máscara (28 de março a 21 de abril de 2022) e durante um período após o fim da obrigatoriedade de uso de máscara (22 de abril a 15 de maio de 2022), em Portugal Continental e nos Açores. Numa segunda fase, para cada região autónoma, ajustou-se um modelo de regressão binomial negativa, tendo como variável de interesse os casos diários de COVID-19 e como variável explicativa a frequência relativa da linhagem Omicron BA.5.

Resultados: Foi observada uma alteração significativa nas tendências relativas à taxa de incidência e mortes por COVID-19; foi observada uma tendência crescente quer para a incidência, quer para as mortes por COVID-19 no período pós-obrigatoriedade de uso de máscara [5,3% por dia; razão da taxa de incidência (IRR): 1,053; intervalo de confiança (IC) a 95%: 1,029 - 1,078] e [3,2% por dia; razão da taxa de mortalidade (MRR): 1,032; IC 95%: 1,003 - 1,062], respetivamente. Para cada aumento de 1% na linhagem BA.5 da variante Omicron estimou-se um aumento de 1,5% por dia (IRR: 1,015; IC 95%: 1,006 - 1,024) na taxa de incidência de COVID-19 na região autónoma dos Açores, enquanto que para a região autónoma da Madeira se observou um aumento de 0,05% nos casos de COVID-19 diários (IRR: 1,005; IC 95%: 1,000 - 1,010).

Conclusão: O fim da obrigatoriedade do uso de máscara em Portugal esteve associado a um aumento na incidência e mortes por COVID-19, destacando-se assim o efeito positivo desta medida de saúde pública na prevenção da transmissão de vírus respiratórios e na redução da mortalidade.

Palavras-chave: COVID-19; Máscaras; Pandemia; Portugal; SARS-CoV-2

INTRODUCTION

The use of face masks was one of several COVID-19 non-pharmaceutical interventions (NPIs) adopted to mitigate the pandemic in Portugal. This intervention was part of a multi-layered approach that emphasized vaccination, included restrictions enforced by the government with different stringency levels and duration periods, and recommended preventive actions at all times, such as respiratory etiquette, physical distancing, and hand hygiene. Mask use,

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closure of nightclubs, limits to public gatherings, and the requirement to present a COVID-19 digital certificate to access restaurants, were some of the compulsory restrictions implemented during longer time periods in Portugal.[1]

However, as the pandemic moved into the next phase, with high vaccination coverage rates as well as anti-viral treatments becoming available, and much lower rates of severe illness, several mandatory restrictions started to be lifted one step at a time. Apart from the requirement, which is no longer in place, for people who test positive for COVID-19 to self-isolate, mask use required in all indoor public spaces in the mainland Portugal since the 30th April 2020, was one of the last restrictions to be lifted. On the 22nd April 2022, mask use was no longer compulsory in indoor spaces, except in public transportation, access to healthcare services, and long-term care facilities.[2] This NPI was also lifted in the Azores islands but continued in place in Madeira islands until the 15th May 2022. Between April 22, 2022 and April 17, 2023, mask use was only required in healthcare institutions and long-term care facilities.[3]

Other European countries, such as Denmark, Norway, and the UK had already abolished the mandatory use of face masks in indoor public areas, between February and April 2022, at the peak of COVID-19 epidemic waves. Moreover, although a high number of cases was registered at the time, the epidemic continued its descending trajectory.[4,5] Opposite results, however, had been observed in some American states in 2021, where after mask mandates were lifted increasing trends of the epidemic were observed.[6]

There is a large body of evidence supporting the efficacy of public mask wearing in controlling COVID-19 transmission and as a consequence, in preventing COVID-19 cases and deaths.[7–8] A study on the effectiveness of COVID-19 NPIs during Europe's second wave found that wearing masks in public led to a reduction in the COVID-19 reproduction number of around 12%.[9] Another modelling study analysing COVID-19 mortality rates across 44 countries, including Portugal, showed that face mask mandates were associated with lower COVID-19 death rates.[10] Nevertheless, most studies examined the impact of mask mandates, and very few focused on the impact of lifting this NPI.[11]

We intended to address this gap by evaluating the impact of lifting the mask mandate on COVID-19 incidence and mortality in Portugal. First, we evaluated changes in COVID-19 cases and mortality trends pre- and post-lifting of the mask mandate in mainland Portugal and in the Autonomous Region of the Azores. As the lifting of mask mandates coincided with the evolution of the Omicron BA.5 lineage in Portugal, in a second phase we aimed to evaluate the evolution of COVID-19 cases in a setting without a mask mandate (Azores islands) and in a setting with a mask mandate in place (Madeira islands).

METHODS

Study design and population

An ecological study was performed using an interrupted time series analysis to estimate the impact of lifting mask mandates, on the 22nd April 2022, on the development of COVID-19 infections and deaths. For the main analysis the target population comprised residents of mainland Portugal (North, Center, Lisbon and Tagus Valley, Alentejo and Algarve) and the autonomous region of Azores. We excluded Madeira islands from the main analysis as this autonomous region only lifted the mask mandate on the 15th May 2022.

The Omicron BA.5 lineage was detected for the first time in the week 13/2022 (28th March – 3rd April 2022) and became dominant in Portugal (estimated relative frequency of 78.7%, as of May 23, 2022).[12] As the growth rate of COVID-19 variants is time-dependent it prevented us from adjusting our interrupted time series regression for the relative frequency of the Omicron BA.5 lineage. Consequently, in a second phase, we used a quasi-experimental research design to evaluate the evolution of COVID-19 cases, using the relative frequency of the Omicron BA.5 lineage as explanatory variable, in a setting without a mask mandate (Azores islands) and in a setting with a mask mandate (Madeira Islands). We purposely chose these two regions because they are similar in terms of population size and, since they are geographically isolated, Omicron BA.5 lineage circulation was delayed compared to mainland Portugal, giving us a unique opportunity to evaluate if a mask mandate could have mitigated the impact of the pandemic even in the presence of a highly transmissible variant.

Outcome variables

We used national surveillance data concerning the daily number of SARS-CoV-2 laboratory-confirmed infections and COVID-19 deaths in Portugal provided by the Directorate General of Health (DGS).[13] The provided dataset also included the date of symptom onset, date of diagnosis and date of confirmation/notification for each case. Imputation methods, described in previous studies, were used to estimate missing dates of disease onset.[14,15] Daily counts of COVID-19 cases by date of symptom onset were used to perform all statistical analyses regarding incidence, while for the analysis regarding mortality, date of death was considered.

The most recent resident population counts, extracted from Statistics Portugal, were used as denominators to compute incidence and mortality rates.[16]

Covariates

The weekly relative frequency of Omicron BA.5 lineage, by specimen collection date, in Portugal was made available by the National Health Institute Doutor Ricardo Jorge.[17] The

daily relative frequency of Omicron BA.5 lineage was computed using linear interpolation.

Lag periods

The evidence suggests there is a three day median lag time between SARS-CoV-2 Omicron variant transmission and symptom onset.[18] Furthermore, a symptom-onset-to-death delay was estimated through analysis of the lag distribution between COVID-19 onset of symptoms and death. This resulted in a potential lag of three days between the end of the mask mandate and associated COVID-19 incidence and an overall likely lag of 13 days between the end of the mask mandate and associated COVID-19 mortality. These durations underpin a choice of 3- and 13-day lags, respectively, for modelling the impact of lifting the mask mandate on COVID-19 incidence and mortality and for the decision to use a 10-day extension in the mortality analysis study period.

Study period

To control for the effects of simultaneously occurring interventions, the beginning of the observation period in our analysis was chosen considering the first confirmed case of the Omicron BA.5 lineage in Portugal, while the ending was chosen considering the administration of the second booster dose of COVID-19 vaccine for the population over 80 years old.[12,19]

Therefore, to assess the change in trend in COVID-19 incidence in mainland Portugal and Azores islands before and after lifting the mask mandate, we compared two periods (Fig. 1): (i) a mask mandate period from March 28, 2022 to April 21, 2022; (ii) a post-mask mandate period from April 22, 2022 until May 15, 2022.

To assess the change in trend of COVID-19 deaths in mainland Portugal and the Azores before and after lifting the mask mandate, we compared two periods (Fig. 1): (i) a mask mandate period starting on March 28, 2022 until April 21, 2022; (ii) a post-mask mandate period starting on April 22, 2022 until May 25, 2022 (considering a 10-day delay between the onset of disease and death).

As a secondary objective, we evaluated the evolution of COVID-19 cases, using the relative frequency of Omicron BA.5 lineage as an explanatory variable, in a setting without a mask mandate (Azores islands) and in a setting with a mask mandate (Madeira islands). To accomplish this goal, we took into consideration not only the timings of mask mandates in both archipelagos but also periods with equivalent Omicron BA.5 lineage evolution in both settings. Therefore, we used 18th April – 8th May 2022 as the Azores islands observation period (no mask mandate in place) and

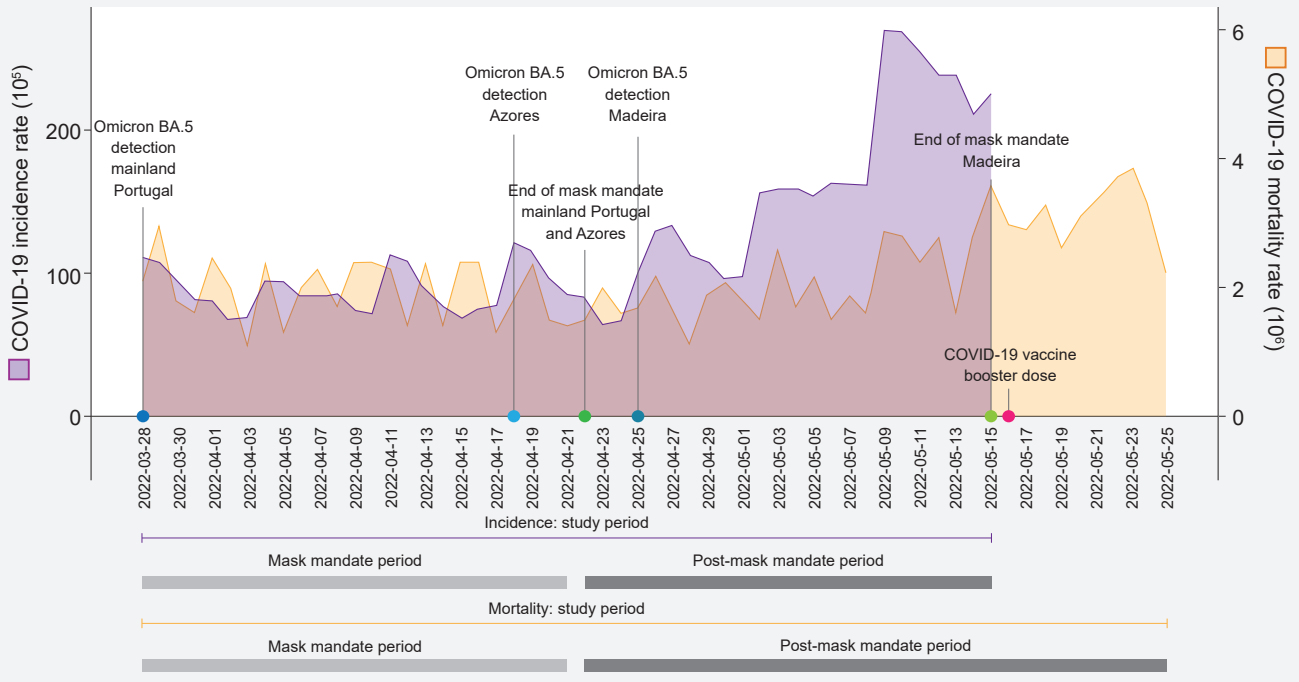

Figure 1 – COVID-19 daily incidence rates[a], COVID-19 mortality rates[b] and timeline of mask mandate lifting, Portugal, 28th March 2022 – 25th May 2022

COVID-19: coronavirus disease; [a]: Per 100 000 population; [b]: Per 1 000 000 population.

Time interval regarding the study period for assessing the impact of lifting the mask mandate in incidence is depicted in purple. The time interval regarding the study period for assessing the impact of lifting the mask mandate in mortality is depicted in orange.

25th April – 15th May 2022 as the observation period for the Madeira islands (mask mandate in place) (Fig. 1).

Statistical analysis

To estimate changes in COVID-19 daily incidence and mortality before and after lifting the mask mandate we used an interrupted time series analysis, fitting separate models for each outcome.

A negative binomial regression model was adjusted, with daily COVID-19 incident cases as the primary outcome of interest, whereas for COVID-19 deaths a Poisson regression model was used. Explanatory factors included the linear effect of time (slope) and change in trend after lifting the mask mandate (change in slope). The population was included in models as an offset variable.

Due to the SARS-CoV-2 Omicron variant, median incubation period of three days, for the incidence regression model, we included a lag of three days in explanatory variables.[17] For the regression model applied to COVID-19 deaths, we included a lag of 13 days in explanatory variables.

The statistical models used in the main analysis, for COVID-19 cases and deaths, were given as follows:

(cases) $logE(C_t) = \beta_0 + \beta_1 Time_t + \beta_2 Time_t \times Mask_{t-3} + log(Pop_t)$

(deaths) $logE(D_t) = \alpha_0 + \alpha_1 Time_t + \alpha_2 Time_t \times Mask_{t-13} + log(Pop_t)$

where C_t and D_t are daily counts of COVID-19 cases and deaths by the time of symptom onset or date of death (t), respectively; exp(β_0) and exp(α_0) are the incidence and mortality rate at Time = 0; $Time_t$ is time in days since the start

Table 1 – Daily trends in the COVID-19 incidence rate before and after lifting mask mandate, March 18 – May 15, 2022 (n = 607 760) and daily trends in the COVID-19 mortality rate before and after lifting mask mandate, March 28 – May 25, 2022 (n = 1 302), mainland Portugal and Azores islands

	Mask mandate		Post-mask mandate		Change in trend	95% CI	*p* value[a]
	28th Mar – 21st April 2022		22nd April – 15th May 2022				
COVID-19 incidence rate	**IRR**	**95% CI**	**IRR**	**95% CI**			
	1.005	0.997 - 1.013	1.053	1.029 - 1.078	1.048	1.032 - 1.064	< 0.001
	28th Mar – 21st April 2022		22nd April – 25th May 2022				
COVID-19 mortality rate	**MRR**	**95% CI**	**MRR**	**95% CI**			
	0.999	0.989 - 1.009	1.032	1.003 - 1.062	1.033	1.014 - 1.053	< 0.001

CI: confidence interval; COVID-19: coronavirus disease; IRR: incidence rate ratio; MRR: mortality rate ratio

[a]: Two-sided Wald test *p* values were obtained from negative binomial regression models. A *p*-value < 0.05 was considered evidence of statistical significance.

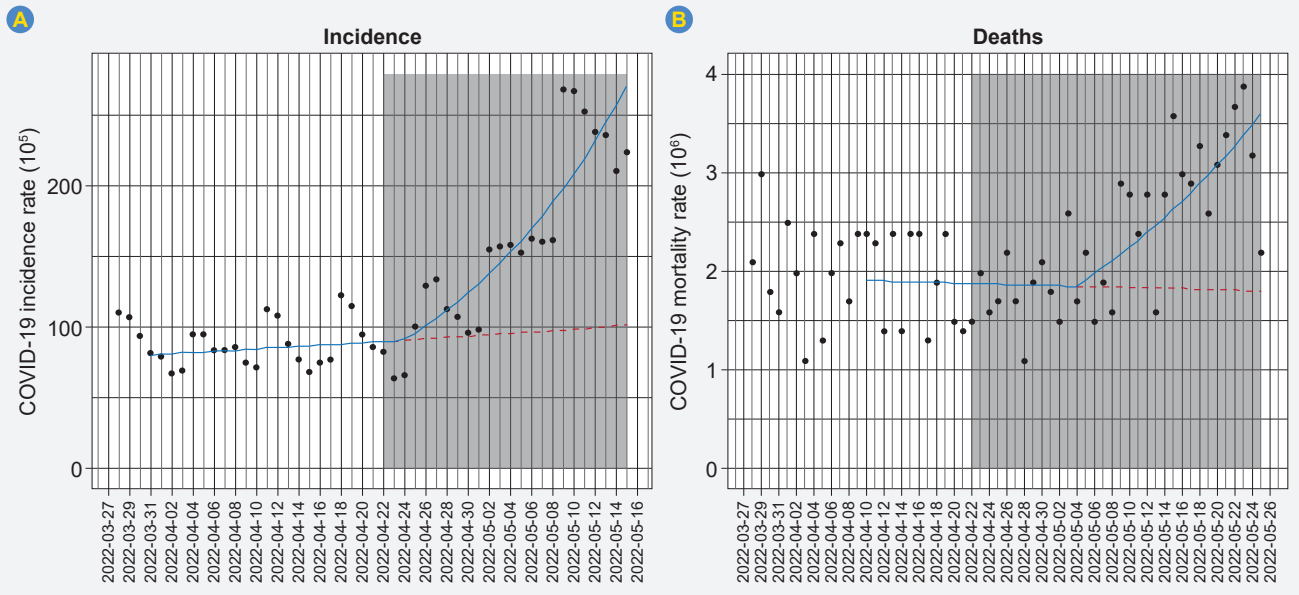

Figure 2 – COVID-19 daily incidence rates. (A) 28th March – 15th May 2022 (n = 607 760) and COVID-19 daily mortality rates; (B) 28th March – 25th May 2022 (n = 1 302) before and after lifting mask mandate, mainland Portugal and Azores islands

COVID-19: coronavirus disease; [a]: Per 100 000 population; [b]: Per 1 000 000 population.

The shaded grey area represents the period after lifting the mask mandate. Blue solid lines represent the fitted incidence and mortality rates before and after lifting mask mandate, respectively. The red dashed line represents the predicted incidence and mortality rate in a counterfactual scenario, i.e. if the mask mandate had not ended.

of the study period; $Mask_{t-3}$ and $Mask_{t-13}$ are dummy variables representing, the end of mask mandate (0 in mask mandate period, 1 otherwise); exp(β_1) and exp(α_1) are the slope of the outcome variable until the end of the mask mandate; exp(β_2) and exp(α_2) are the change in slope after lifting of the mask mandate; Pop_t represents the population at time *t*.

The daily percentage change of COVID-19 incidence and mortality in the post-mask mandate periods was calculated as 100% [incidence rate ratio (IRR)−1] and 100% [mortality rate ratio (MRR)−1], respectively, where IRR and MRR were estimated as exp($\beta_1+\beta_2$) and exp($\alpha_1+\alpha_2$), respectively.

As a secondary objective, for each group of islands, we fitted a negative binomial regression model, with daily COVID-19 incident cases as the primary outcome of interest, and relative frequency of Omicron BA.5 lineage as explanatory variable, as follows:

(BA.5 lineage) $logE(C_t) = \beta_0 + \beta_1 BA5_t + log(Pop_t)$

where C_t is a daily count of COVID-19 cases by time of symptom onset (t); exp(β_1) is the percent change in the incident rate of COVID-19 for every unit increase in BA5; $BA5$ is the relative frequency of Omicron BA.5 lineage; Pop_t represents the population at time t.

The level of significance was set at 5% for all tests. Model goodness-of-fit was assessed by graphical analyses of residuals and Pearson's chi-squared test. R version 3.5.1[20] was used to perform statistical analyses.

The aggregated data used within this study were anonymised and collected in the scope of epidemiological surveillance and therefore submission to an ethics committee was not required.

RESULTS

Trends in COVID-19 incidence and death rates

In the mask mandate period (28th March – 21st April 2022) a stable trend was observed for the COVID-19 incidence rate (IRR: 1.005; 95% CI: 0.997 - 1.013). In the post-mask mandate period (22nd April – 15th May 2022), a statistically significant change in trend was observed for the incidence rate. A significant increasing trend was observed in mainland Portugal (5.3% per day; IRR: 1.053; 95% CI: 1.029 - 1.078) (Table 1 and Fig. 2).

A stable trend was observed during the mask mandate period (28th March – 21st April 2022) for the COVID-19 mortality rate (MRR: 0.999; 95% CI: 0.989 - 1.009). In the post-mask mandate period (22nd April – 25th May 2022), a statistically significant change in trend was observed for the mortality rate. A statistically significant increasing trend was observed (3.2% per day; MRR: 1.032; 95% CI: 1.003 - 1.062) (Table 1 and Fig. 2).

Evolution of COVID-19 incidence in settings without (Azores) and with (Madeira) mask mandates

The Omicron BA.5 lineage was detected in week 13 of 2022 in mainland Portugal. However, the first confirmed samples of Omicron BA.5 lineage in the Azores and Madeira islands were only detected in week 16 of 2022 and week 17 of 2022, respectively. An increasing trend in the relative frequency of the Omicron BA.5 lineage was observed in the Azores islands from the 18th April to the 8th May 2022 and in the Madeira islands from the 25th April to the 15th May 2022. For these observation periods, the maximum estimates in each region were 26.7% in week 18 of 2022 for the Azores islands and 34.4% in week 19 of 2022 for the Madeira islands (Appendix 1: https://www.actamedicaportuguesa.com/revista/index.php/amp/article/view/18974/15137).

For every unit increase in the percentage of Omicron BA.5 lineage there was a 1.5% increase per day (IRR: 1.015; 95% CI: 1.006 - 1.024) in COVID-19 incidence rate in the Azores islands, while for the Madeira islands an increase of 0.05% COVID-19 cases per day was observed (IRR: 1.005; 95% CI: 1.000 - 1.010) (Fig. 3 and Table 2).

DISCUSSION

Our findings suggest that lifting the mask mandate was associated with an increase of the number of COVID-19 cases in mainland Portugal and Azores. These results are in line with a study from the United States which found an increase of 12 per 100 000 daily new COVID-19 cases after state and county level mask mandates were lifted in January 2021.[6] Additionally, as the efficacy of public mask wearing in preventing the spread of COVID-19 is largely supported by epidemiological and ecological data, as well as models, this adds to the body of evidence that lifting mask mandates should have an impact on the COVID-19 transmission.[7–9] However, the impact of mask mandates may go beyond the direct impact on COVID-19 incidence and may be an indirect consequence of changes in mobility or altered risk perception. A study evaluating the effects of NPIs and population mobility on daily COVID-19 cases in Ontario, Canada, found that the implementation of mask mandates in indoor settings was correlated with reductions in social mobility.[21] In Portugal, mobility trends for retail and recreation, parks, and public transport hubs such as subway, bus, and train stations, increased after mask mandates were lifted [compared to the period with mask mandates (28th March – 21st April 2022)], which suggests that lifting the mask mandate may also have an indirect impact on increasing the number of daily cases through population behavioural changes.[22] Additionally, a Portuguese study suggested that risk perception may be associated with restrictions imposed to mitigate the pandemic, which corroborates the hypothesis that the population may reduce their preventive behaviours with

Figure 3 – COVID-19 daily incidence rates and weekly relative frequency of BA.5 Omicron lineage, in the Azores islands (April 18 - May 8, 2022) (n = 8 751 COVID-19 cases; n = 173 sequenced COVID-19 samples) and the Madeira islands (April 25 – May 15, 2022) (n = 4 192; n = 105 sequenced COVID-19 samples)
COVID-19: coronavirus disease, [a]: Per 100 000 population.

Table 2 – Daily trends in the COVID-19 incidence rate before and after lifting the mask mandate, in Azores islands (April 18 - May 8, 2022) (n = 8 751) and Madeira islands (April 25 - May 15, 2022) (n = 4 192)

Area	Change in IRR	95% CI	*p* value[a]
Azores islands (18 April - 8 May, 2022)	1.015	1.006 - 1.024	<0.001
Madeira islands (25 April - 15 May, 2022)	1.005	1.000 - 1.010	0.042

COVID-19: coronavirus disease; CI: confidence interval; IRR: incidence rate ratio.
[a]: Two-sided Wald test *p* values were obtained from negative binomial regression models. A *p* value < 0.05 was considered evidence of statistical significance.

the end of mask mandates.[23] We also note that restrictions on mass gatherings had already been lifted before mask mandates were abolished in Portugal. Therefore, infections arising from settings with substantial population mixing may have been amplified with the end of mask mandates, as a Japanese study on COVID-19 risk assessment in professional baseball and football games found that the infection risk increased as the face-mask-wearing proportion

decreased in those settings.[24]

Even though other European countries, such as Denmark, Norway, and the UK, did not register an increase in COVID-19 incidence after the end of mask mandates, we note that NPI were lifted at the peak of COVID-19 epidemic waves with outstanding numbers of cases and, thus, those populations may have benefited from increased immunity after a COVID-19 infection.[4,5] The Portuguese population, however, was at risk of waning immunity as approximately three months had passed since the last epidemic wave in Portugal (December 2021 – February 2022) and a first booster dose of COVID-19 vaccine had been administered in the early winter months.[25] In addition, apart from South Africa, Portugal was one of the first countries where the Omicron BA.5 lineage was detected.[26] Recent findings indicated an increase of the Omicron BA.5 lineage relative to other variants in its capacity to infect, and be transmitted from, previously infected and vaccinated individuals.[26,27] In fact, the transmission advantage of the Omicron BA.5 lineage seems to stem from its capacity to infect individuals who were immune, not only to other COVID-19 variants, but also to earlier forms of Omicron.[28] This leverage may have contributed to the rise of the Omicron BA.5 lineage in Portugal and could be a possible explanation for its growth advantage relative to other variants in circulation at the time.

Our results suggest that the end of the mask mandate was associated with an increase in COVID-19 deaths in mainland Portugal and the Azores islands. A study conducted in the United States found no statistically significant effect on deaths associated with lifting mask mandates between January and March 2021. Nevertheless, the authors note this could be due to limited data from the recent states which lifted mask mandates.[6] On the other hand, a modelling study on COVID-19 scenarios for the United States projected that universal mask use could save an additional 129 574 lives between September 22, 2020 and the end of February 2021, thus providing supporting evidence that the end of mask mandates can have a potential impact on COVID-19 mortality.[29] Similar results were found in another modelling study analysing COVID-19 mortality across 44 countries, including Portugal: countries without face mask mandates had an average daily increase of 0.0533 deaths per million, compared with the average daily increase of 0.0360 deaths per million for countries with face mask mandates.[10] We note, nonetheless, that after the end of the mask mandate, the incidence of COVID-19 in Portugal experienced a high increase in age groups over 60 years old, which can explain the increased mortality rates observed.[25]

As mask mandates were lifted at different time points in the Portuguese autonomous regions, we took advantage of this difference to compare trends in COVID-19 infections in a setting without a mask mandate (Azores islands) and in a setting with a mask mandate in place (Madeira islands), using the relative frequency of Omicron BA.5 lineage as explanatory variable. Compared with a setting with a mask mandate, we found that without a mask mandate in place, a higher growth rate of COVID-19 cases was observed with the increase of the Omicron BA.5 lineage. This suggests that mask mandates appear to have mitigated COVID-19 transmission in Madeira islands even in the presence of a more transmissible COVID-19 variant. Such results are broadly in line with findings from studies that, taking advantage of the asynchronous mask mandates across Germany, created artificial controls and then estimated that face masks reduced the daily growth rate of COVID-19 infections by around 47%.

Our study has some limitations. It is plausible that the waning immunity of the Portuguese population is an important factor which we did not account for in our analysis. Nonetheless, waning immunity, in addition to high transmissibility of the Omicron BA.5 lineage and limited vaccine effectiveness against Omicron infection, suggest there is added value to wearing masks, particularly to prevent COVID-19 morbidity and mortality.[26,27,31]

We accounted for a lag between infection and disease onset in our regression models, and this may be considered a strength of our study, as it provides us a more precise interpretation of the impact of lifting the mask mandate in Portugal. However, there is limited information on the Omicron BA.5 lineage and, consequently, we assumed an incubation period similar to that of the Omicron BA.1 lineage.[18] We point out though, that we do not expect the incubation period to differ significantly between these two lineages as they derived from a common ancestor and, therefore, are genetically closely related.

Another limitation of our study is the increase of the Omicron BA.5 lineage during our study period. As the relative frequency of the Omicron BA.5 lineage is time-dependent we did not control for confounding in our interrupted time series analysis. Yet, by using a quasi-experimental design in addition to the main analysis we added evidence that mask mandates may mitigate the spread of the Omicron BA.5 lineage, which can be more robust than merely presenting estimates in a “before – after” manner with no use of a strict control group approach.

Finally, the ecological approach of this study requires some caution in the interpretation of its results, as it cannot be inferred that lifting the use of mask at a population level, will necessarily increase the risk of COVID-19 disease at individual level (‘ecological fallacy’). It was not possible to control adequately for confounders, effect modifiers and mediators at the individual level and therefore the present study has potential susceptibility to aggregation bias and unknown sources of confounding.[32] Nonetheless, to some

extent, the aggregation of data was unavoidable since the main predictor of interest, lifting the mask use, was measured at the population level and, hence, is an ecological variable.

CONCLUSION

Lifting the mask mandate in Portugal was associated with an increase in COVID-19 incidence and deaths, which highlights the positive effect of face mask policies in preventing respiratory virus transmission and saving lives. These results may, therefore, aid public health authorities in choosing appropriate mitigation measures for future pandemics.

AUTHORS CONTRIBUTION

All authors contributed equally to this manuscript.

PROTECTION OF HUMANS AND ANIMALS

The authors declare that the procedures were followed according to the regulations established by the Clinical Research and Ethics Committee and to the Helsinki Declaration of the World Medical Association updated in 2013.

DATA CONFIDENTIALITY

The authors declare having followed the protocols in use at their working center regarding patients' data publication.

COMPETING INTERESTS

The authors have declared that no competing interests exist.

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