*Disaster Medicine and Public Health Preparedness*

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## Original Research

**Cite this article:** Keser M, Sariyer G, Kahraman S. Event study design for modeling early relaxation in Turkish public with COVID-19 vaccine. *Disaster Med Public Health Prep*. **17**(e478), 1–6. doi: https://doi.org/10.1017/dmp.2023.147.

**Keywords:**
COVID-19; public health; stringency index; vaccine

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# Event Study Design for Modeling Early Relaxation in Turkish Public with COVID-19 Vaccine

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## Abstract

**Objective:** Vaccination is crucial to fighting the coronavirus disease (COVID-19) pandemic. A large body of literature investigates the effect of the initiation of the COVID-19 vaccination in case numbers in Turkey, including the resistance and willingness to taking the vaccine. The effect of early relaxation in the Turkish public with the initiation of vaccination on new daily cases is unknown.

**Methods:** This study performs an event study analysis to explore the pre-relaxation effect of vaccination on the Turkish public by using daily data of new cases, stringency index, and residential mobility. Two events are comparatively defined as the vaccination of the health personnel (Event 1) and the citizens age 65 and over (Event 2). The initial dates of these events are January 13 and February 12, 2021, respectively. The length of the estimation window is determined as 14 days for the 2 events. To represent only the early stages of the vaccination, the study period ends on April 12, 2021. Thus, whereas the event window of Event 1 includes 90 observations, Event 2 covers 60 observations.

**Results:** While average values of residential mobility, stringency index, and daily numbers of cases are 15.36, 71.03, and 11 978.93 in the estimation window for Event 1, these averages are 8.89, 70.88, and 17 303.20 in the event window. For Event 2, the same average values are 9.14, 69.38, and 7 664.93 in the estimation window and 8.25, 71.12, and 22 319.10 in the event window. When 14-day abnormal growth rates of the daily number of cases for Event 1 and Event 2 are compared, it is observed that Event 1 has negative growth rates initially and reaches a 7.59% growth at most. On the other hand, Event 2 starts with a 1.11% growth rate, and having a steady increase, it reaches a 23.70% growth in the last 14 days of the study period.

**Conclusion:** The preliminary result shows that, despite taking more strict governmental measures, while residential mobility decreases, the daily number of COVID-19 cases increases in the early stages of vaccination compared to short pre-periods of it. This indicates that the initiation of vaccination leads to early behavioral relaxation in public. Moreover, the effect of Event 2 on the case numbers is more significant and immediate, compared to that of Event 1, which may be linked to the characteristic of the Turkish culture being more sensitive to the older adult population.

The novel coronavirus SARS-CoV-2 has been spread from Wuhan, China, in December 2019. Consequently, coronavirus disease (COVID-19) is declared a pandemic by the World Health Organization on March 11, 2020.[1] In fighting against the pandemic, there exist tremendous worldwide efforts to keep the spread of the virus under control and protect the functioning of health systems.[2,3] Mask-wearing and stay-at-home campaigns and obligations, travel bans, school and work closures, entertainment place closures, and so on, are just a few of the policies taken by governments in managing the pandemic environment.

The COVID-19 vaccine is perceived as salvation from the health threats created by this disease and the pressure environments created by the measures taken in the fight against this pandemic.[4] These trigger intense global research and development activity for developing a vaccine against COVID-19.[5] As the COVID-19 vaccine is developed and people start to be vaccinated, research on the effects of this vaccine from various perspectives takes its place in the literature. The large body of the literature investigates the impact of the vaccine on the COVID-19 spread indicators (such as the number of cases, deaths, intensive care unit patients) and the rate of these effects.[6–8]

From the human behavior perspective, while most studies analyze willingness to vaccinate,[9–11] some of the others study hesitancy and resistance to vaccines.[12,13] Some existing literature analyzes the relaxation of governmental restrictions with COVID-19 vaccination,[14] although current research argues that to gain "herd immunity" protection against the COVID-19 virus, at least 60-80% of the population need to be immunized.[15,16] A literature gap is identified in the early public relaxation with vaccination initiation.

In this study, by performing an event study design, we aim to investigate early relaxation in the Turkish public with vaccination. In this design, 2 specific dates showing the initiation of the COVID-19 vaccine in 2 different groups are taken as events. The first group is identified as the health personnel, and the second one is the people age 65 and over. Thus, with this study, we aim to address the following research questions:

*RQ1*. Does the initiation of vaccination of health personnel and the older adult population create an early relaxation in the Turkish public?

*RQ2*. Does a significant difference exist between the impacts of the initiation of vaccination of health personnel and the older adult population?

By responding *RQ1* and *RQ2* with a proposed event study methodology, while we aim to show that early stages of vaccination can create an early relaxation in public, we also contribute to the existing literature by highlighting the need for a large portion of the population to be vaccinated to gain immunity against COVID-19.

The rest of this paper is organized as follows: *Methods* presents the data and the methodology. *Results* shows the findings of this study by summarizing the preliminary descriptive results and abnormal growth rates in case numbers, and by providing a robustness analysis. *Discussion* represents the discussions and interpretations of the study findings considering the existing studies. *Conclusion* shows the concluding remarks, limitations of this study, and future research directions.

## Methods

Daily data on new cases, total cases, stringency index, and residential mobility for Turkey are obtained from Our World in Data,[17] which is publicly available. Residential mobility is a statistic used to determine whether people stay at home. A low value indicates that people do not stay at home much, whereas a high value indicates that people do not go out of their homes much.

While analyzing and comparing the spread rate of COVID-19 before and just after the initiation of vaccination, daily data on new cases are used. However, to make a fair comparison between the before and after periods, we also need to show that no significant relaxation exists in governmental measures. Thus, the measure of government response, namely the stringency index, is defined as the control variable of this study.

To calculate the government restriction policies quantitatively, we use *Oxford COVID-19 government response tracker,*[18] which evaluates 9 different policies: school closures, workplace closures, cancellation of public events, restrictions on public gatherings, closures of public transport, stay-at-home requirements, general information campaigns, restrictions on internal movements, and international travel controls. To measure how vaccine results in behavioral changes in public, we use human mobility data released by Google as a time-limited sharing.[19]

An event study is designated to examine the early effect of the initiation of vaccination on the daily number of new cases in Turkey. The first studied event is the initiation of vaccination in Turkey when the Minister of Health and immediately afterward the health care personnel start to be vaccinated. The date of this event is January 13, 2021. Thus, this specific date indicates $t = 0$ for Event 1. Since the aim of this study is to investigate whether initiation of vaccination causes an early relaxation in the Turkish public, a short study period must be defined. Otherwise, the concept of early relaxation would be meaningless if a period is defined to cover the vaccination of the majority of the population. We, therefore, define a short event window covering a 3-month period. Thus, the event window of this study is taken from January 13, 2021 ($t = 0$) to April 12, 2021 ($t + 89$). On the other hand, to analyze the short pre-periods of the vaccination, which is defined as the estimation window of the event study, the use of 14 days is defined. Thus, the estimation window of Event 1 is determined as December 30, 2020, to January 13, 2021.

The initiation of vaccination in the older adult population is identified as another event of this study. Since the start date of this event is different from the initiation of vaccination of the health personnel, the event window of this event is defined from February 12, 2021 ($t = 0$) to April 12, 2021 ($t + 59$). By using 14 days, the estimation window of Event 2 is determined as January 29, 2020, to February 12, 2021. Figure 1 represents the estimation and event windows of the designated 2 events.

In this study, the estimation windows' data show the short pre-period before vaccination, and the event windows' data represent the early stages of vaccination. For comparing the spread of COVID-19 before and just after the initiation of vaccination, abnormal growth rates (AGR) in daily cases are analyzed. AGR is calculated with the difference between expected and observed case growth. Expected case growth is calculated with the estimation window's average case growth. To obtain $AGR_{NC}$, the difference between the growth rate of daily observed ($NCgrowth^t_{obs}$) and estimated ($NCgrowth^t_{est}$) cases is calculated in Equations 1–3.

$$NCgrowth^t_{obs} = ln(TC_t) - ln(TC_{t-1}) \tag{1}$$

$$NCgrowth^t_{est} = ln(TCE_t) - ln(TCE_{t-1}) \tag{2}$$

$$AGR^t_{NC} = NCgrowth^t_{obs} - NCgrowth^t_{est}. \tag{3}$$

where $TC_t$ and $TCE_t$ equations and 1 and 2 denote observed and estimated growth values in total case growth on day *t,* respectively.

## Results

### Preliminary Results

As a pre-analysis, we show the daily values of the study variables comparatively in short pre-periods and early stages of the vaccination.

In Figure 2a, we observe that, although the number of daily new cases decreases until mid-January, it starts to increase thereafter. Besides, the growth rate in the daily numbers of new cases has a sharp change after mid-March. Based on the stringency index values shown in Figure 2b, we observe that, although it reaches the highest values (around the 80s) just for a few days at the beginning of January, this variable generally has higher values after the initiation of vaccination compared to pre-periods. In Figure 2c, we also observe that residential mobility almost always has lower values in the early stages of vaccination compared to the pre-periods.

Table 1 shows the summary statistics of the study variables during the estimation and event window intervals for the 2 events.

Table 1 shows that the stringency index is almost the same or slightly higher in the short pre-periods of the vaccination compared to the early stages of it for both Event 1 and Event 2. On the other hand, a significant decrease is seen in residential mobility statistics in the early stages of the vaccination compared to the pre-periods for both events. Similarly, it is observed that daily

https://doi.org/10.1017/dmp.2023.147 Published online by Cambridge University Press

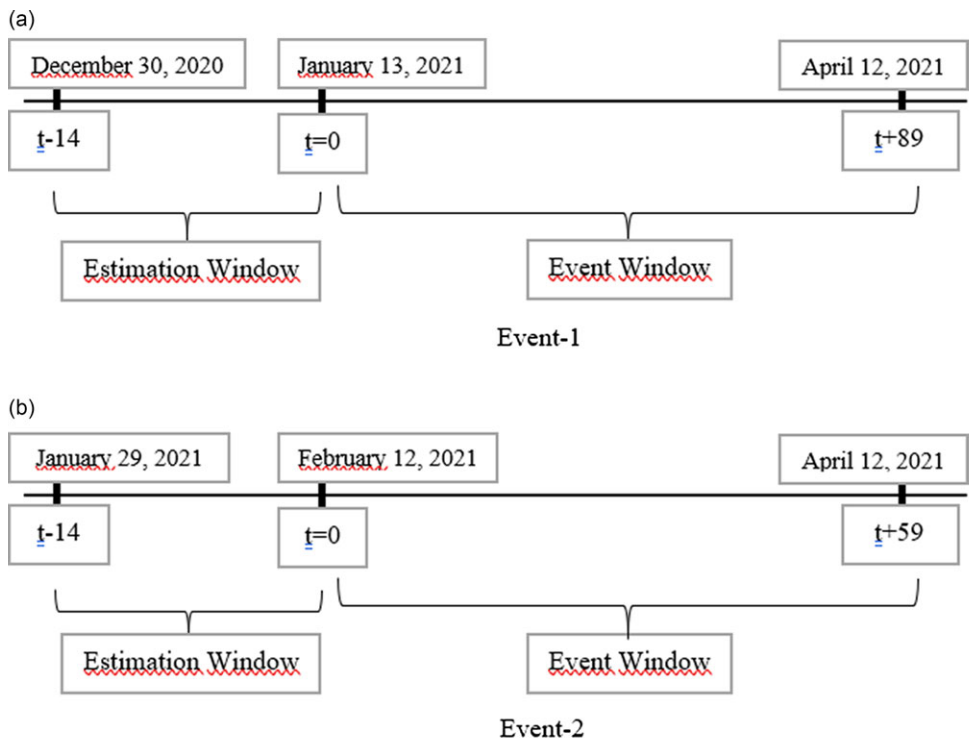


**Figure 1.** Estimation and event windows.

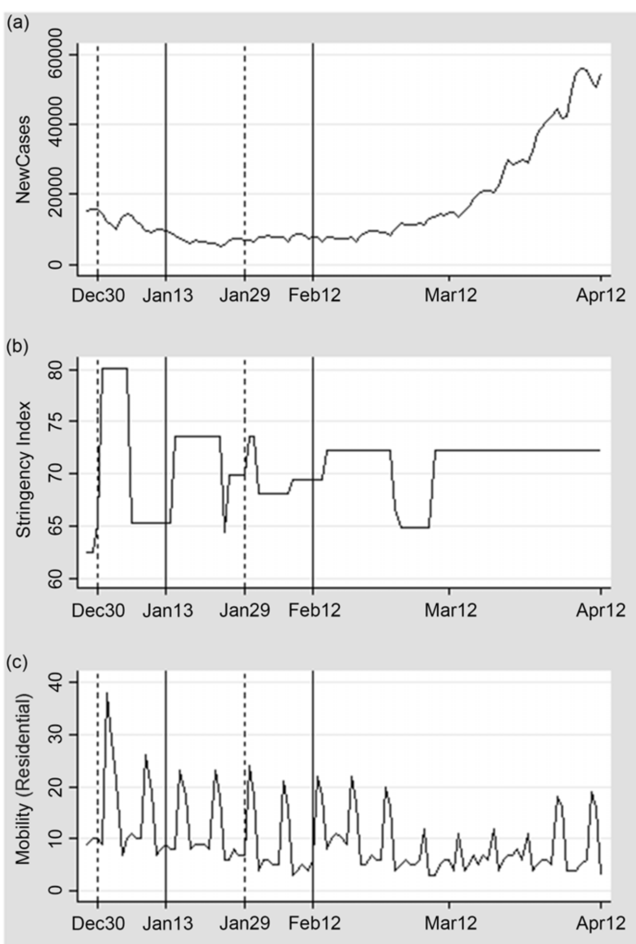


**Figure 2.** Daily values of study variables.

numbers of new cases are significantly increased in the early stages of vaccination.

### *Abnormal Growth in Total Cases*

Figure 3 shows the growth rate in total cases (CaseGrowth), abnormal growth rate (AGR), and cumulative abnormal growth rates (CAR).

In Figure 3, we observe CaseGrowth and AGR values are steady until mid-March. However, a dramatic change exists in these values thereafter.

Table 2 presents abnormal growth rates for these 2 events during the event window period.

When we analyze the cumulative abnormal growth rates of the daily number of cases for Event 1, we initially observe negative growth rates. We observe positive growth for Event 1 after mid-March, reaching the level of 7.59%. On the other hand, abnormal growth rates have all positive values for Event 2. While the calculated AGR value starts with a small 1.11% growth, with a steady increase, it reaches a 23.70% growth.

### *Robustness Analysis*

We provide robustness estimation by following the approach presented by Lyu and Wehby.[20] This approach shows a pure event time effect to model cumulative case growth and takes the growth rate of the daily number of total COVID-19 tests as a control variable. The estimated regression model is shown in Equation 4.

$$CCgrowth_t = \beta + \alpha PVAC + \sum_{t=1} \delta_t VAC_t + \theta test_t + \varepsilon_t \quad (4)$$

where cumulative case growth is the $CCgrow_t = ln(C_t) - ln(C_{t-1})$. Vaccination initiation periods (VAC) are binary indicator variables representing the weeks. For weekly periods,

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**Table 1.** The minimum, maximum, and average statistics of the study variables

| | | Event 1 | | Event 2 | |
|---|---|---|---|---|---|
| | | Estimation window | Event window | Estimation window | Event window |
| | Statistics | 12-30-20/01-12-21 | 01-13-21/04-12-21 | 01-29-21/02-11-21 | 02-12-21/04-12-21 |
| Study variables | N | 14 | 89 | 14 | 60 |
| New cases | Min. | 9138 | 5277 | 6562 | 6287 |
| | Max. | 15 692 | 55 941 | 8642 | 55 941 |
| | Average | 11 978.93 | 17 303.20 | 7 664.93 | 22 319.10 |
| Stringency index | Min. | 65.28 | 64.35 | 68.06 | 64.81 |
| | Max. | 80.09 | 73.61 | 73.61 | 72.22 |
| | Average | 71.03 | 70.88 | 69.38 | 71.12 |
| Residential mobility | Min. | 7 | 3 | 3 | 3 |
| | Max. | 38 | 24 | 24 | 22 |
| | Average | 15.36 | 8.89 | 9.14 | 8.25 |

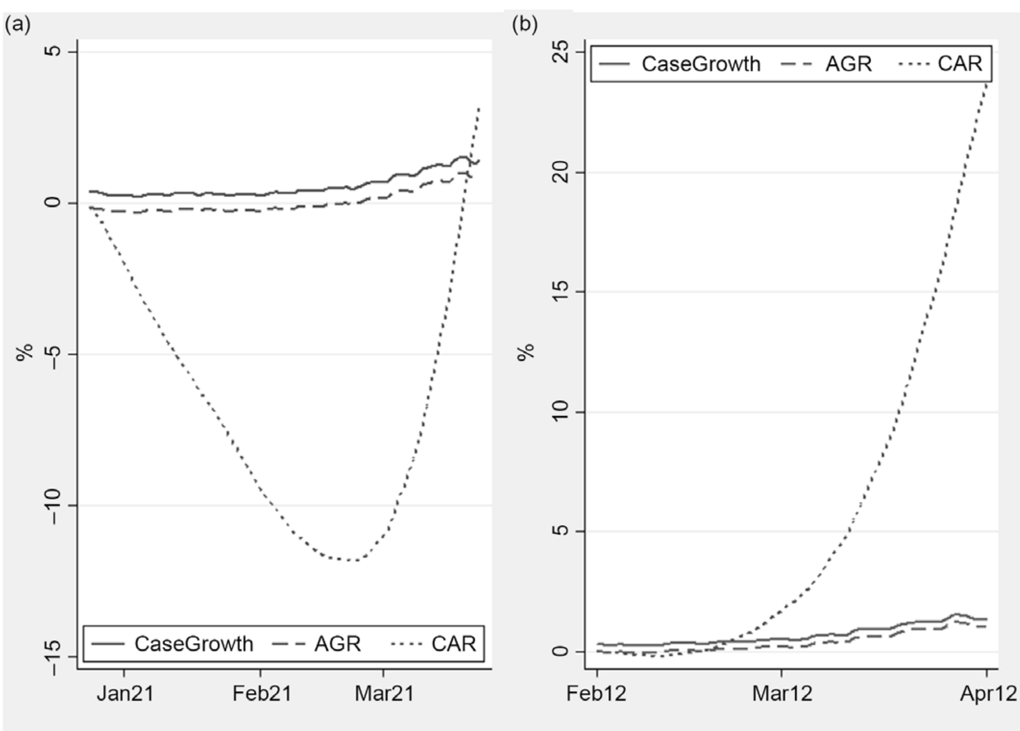


**Figure 3.** AGR and cumulative AGR.

1 pre-vaccination (PVAC) and 10 post-vaccination (VAC1, VAC2, . . . , VAC10) periods are defined for estimating the effect of Event 1. Similarly, 8 post-vaccination periods are defined for the estimation of Event 2. Based on the weekly period definition, periods are arranged to cover 7 days. However, the identified last vaccination periods of the 2 events, VAC10 in Event 1 and VAC8 in Event 2 additionally covered the remaining days of the study period. $\beta$ is the constant of the equation. Similarly, α, $\theta$, and $\delta_t$ are the model parameters.

The test growth rate is calculated with the cumulative total test variable and derived with $test_t = ln(test_t) - ln(test_{t-1})$ in Equation 4. Cumulative case growth and test growth rates have non-normal distribution. Thus, regression estimation is conducted by considering a standard error correction to deal with heteroskedasticity and autocorrelation. For details, see Appendix A. The Event 1 model is estimated using the Newey-West estimator with a sample range between December 21, 2020, and April 4, 2021, having 113 observations. The Event 2 model is

**Table 2.** Cumulative abnormal growth rates

| Date | Event 1 | Event 2 |
|---|---|---|
| 2021-01-27 | −1.22% | – |
| 2021-02-10 | −2.41% | – |
| 2021-02-24 | −5.67% | 1.11% |
| 2021-03-10 | −7.37% | 1.33% |
| 2021-03-24 | −5.67% | 6.17% |
| 2021-04-07 | 3.08% | 18.06% |
| 2021-04-12 | 7.59% | 23.70% |

**Table 3.** Summary results of regression model for robustness

| | Coefficients | | t-statistics | | | Coefficients | | t-statistics | |
|---|---|---|---|---|---|---|---|---|---|
| | Event 1 | Event 2 | Event 1 | Event 2 | | Event 1 | Event 2 | Event 1 | Event 2 |
| **$\beta$** | −0.0097 | −0.0038 | 3.3800*** (0.0029) | −1.822* (0.0021) | **VAC6** | 0.0046 | 0.0049 | 2.9573*** (0.0015) | 9.100*** (0.0005) |
| **PVAC** | −0.0009 | 0.0014 | −2.1799** (0.0004) | 2.478** (0.0006) | **VAC7** | 0.0048 | 0.0068 | 3.2683*** (0.0015) | 9.334*** (0.0007) |
| **VAC1** | −0.0005 | 0.0021 | −0.7807 (0.0007) | 2.697*** (0.0008) | **VAC8** | 0.0050 | 0.0089 | 3.6052*** (0.0014) | 12.975*** (0.0007) |
| **VAC2** | −0.0006 | 0.0024 | −0.6982 (0.0008) | 3.057*** (0.0008) | **VAC9** | 0.0055 | – | 4.1605*** (0.0013) | – |
| **VAC3** | 0.0008 | 0.0028 | 0.6876 (0.0012) | 3.833*** (0.0007) | **VAC10** | 0.0067 | – | 8.7742*** (0.0008) | – |
| **VAC4** | 0.0025 | 0.0033 | 2.1107** (0.0012) | 4.966*** (0.0007) | **TEST** | 2.2388 | 1.2406 | 5.9920*** (0.3736) | 3.294*** (0.3767) |
| **VAC5** | 0.0040 | 0.0040 | 2.7095*** (0.0015) | 6.989*** (0.0006) | | | | | |
| R-square | 0.94 | 0.98 | | | Adjusted R-square | 0.94 | 0.98 | | |

*Note:* *,**, and *** refers to 10%, 5%, and 1% significance levels, respectively. Standard errors are in parentheses.

estimated using the Newey-West estimator with a sample range between January 22, 2021, and April 12, 2021, having 81 observations.

Table 3 provides detailed results of the regression models. The significant effect of Event 1 on the positive growth of cumulative case values is observed when 3 weeks pass (see model coefficients of VAC3). Within 10 weeks, the effect of Event 1 on incremental case growth reaches 0.07%. For each of the 8 weeks of the study period, the significant positive impact of Event 2 is observed in cumulative case growth. The effect of Event 2 on case growth increases each week and reaches 0.09% at the end of the study period.

## Discussion

The findings of this study mainly show that, although the Turkish Government implies more strict responses in the early stages of the vaccination, just after the initiation of vaccination, compared to pre-periods, presenting short before the initiation of vaccination, the Turkish public behaves more relaxed. The decreased residential mobility values in the early stages of the vaccination compared to pre-periods support this relaxation behavior. Undoubtedly, this leads to a sharp increase in the COVID-19 spread and daily case numbers. Additionally, in this study 2 events are identified: the initiation of vaccination of the health personnel and the initiation of vaccination of the older adult population in Turkey. When the abnormal growth rates of these event studies are compared, it is found that Event 2 has significantly higher abnormal growth rates compared to Event 1. This result shows that Event 2 has a more significant impact on the COVID-19 case numbers. The findings of these event studies are discussed in detail in light of literature and Turkish culture in the rest of this section.

Event study methodologies are implemented in the literature to examine the effect of a specific event on the abnormal growths of any variable of interest. This methodology is used in only a few studies in the COVID-19 context. One of these studies is conducted to determine the abnormal growth rate in COVID-19 case numbers of 8 US cities, which can be attributed to the George Floyd protests.[21] Another study aims to estimate the worldwide effects of non-pharmaceutical interventions on COVID-19 incidence and mobility patterns by using a multiple-event design.[22]

As in our study, Li et al.[23] designate an event study analysis to evaluate the effect of vaccination on daily COVID-19 case growth rates in different US cities. Through their research, Li et al.[23] indicate that the vaccination effectively decreases the spread of COVID-19 shortly after the first vaccination is given. However, based on the observed positive abnormal growths in the early stage of the vaccination, the results of this study differ from the related existing study. We attribute these positive growths in the case of numbers to an obtained comparison of the governmental stringency index and the residential mobility between the early stages of vaccination and short pre-periods of it. We, therefore, observe that the Turkish public behaves more relaxed in the early stages of the vaccination. Thus, this change in public behavior, defined as early relaxation, results in increased COVID-19 case numbers.

This opposite finding highlights the importance of the vaccination rate. Although vaccination in Turkey started on January 13, 2021, the vaccination rate is slower compared to many other developed and developing countries. While the vaccination of older adults (age ≥65) started in mid-February, reducing the vaccination age to 60 is realized at the end of March. When the percentage of people vaccinated with the first dose during the study period is checked, we observe that it is only around 8.1% (1.97% of this is fully vaccinated) at the end of February and 10.57% (8% of this is fully vaccinated) at the end of March, which is lower compared to many other countries. Although the vaccination rate gained in significant momentum in June 2021, since the vaccination rate is slower than the behavioral change caused by this vaccine in the first phases of vaccination, an increase is observed in the case numbers contrary to expectations.

In addition, when the abnormal growth in case numbers of the 2 previously mentioned events is compared, we show that the effect of Event 2 on the case growth is more immediate and sharper compared to the impact of Event 1. This finding may be reconciled with a common characteristic of Turkish society and culture: respect of the older adults. The Turkish public has shown its respect for the older adult population during the pandemic as well. This result can be interpreted as people behaving more carefully for protecting their older adults from the disease during the pandemic, and this pressure disappears and turns into early relaxation when the older adults begin to be vaccinated. Additionally, the initiation of vaccination in the older adults may have awakened the thought that their turn will eventually come. This may have caused them to behave more relaxed since the COVID-19 vaccine was perceived as salvation from this pandemic.

As other studies in the literature investigating the impacts of type, level, and timing of the measures taken in the fight against COVID-19,[24–27] these findings can be very insightful for policy-makers since they aim to optimize vaccination levels and timing while maintaining public health in fighting this pandemic. Our study shows that the initiation of vaccination and the early stages of vaccination, when it is not yet long enough for the majority to be

https://doi.org/10.1017/dmp.2023.147 Published online by Cambridge University Press

vaccinated, can create an early relaxation in the population. Thus, in the early stages of the vaccination, by considering the risk of early relaxation in public, the policy-makers shall take stricter actions. Maintaining or increasing the level of pre-vaccination restrictions and prohibitions at least for a certain time can be recommended to policy-makers. Additionally, information campaigns can be launched to ensure that the public does not tend to relax early in the early stages of the vaccination. Otherwise, if the early relaxation effect of vaccination initiation is not taken into consideration by policy-makers, contrary to expectation, an increase in the rate of spread of the pandemic may be seen in the early stages of vaccination.

## Conclusion

Using an event study methodology, we investigate the effect of the initiation of COVID-19 vaccination in case numbers in Turkey. We indicate that, although the government follows similar or even slightly stricter measures in fighting against the pandemic in the early stages of the vaccination compared to short pre-periods of it, the residential mobility data show the opposite. In these initial stages of the vaccination, compared to earlier periods, vaccination caused behavioral relaxation in public in such a way that their residential mobility started to decrease. Therefore, this led to positive abnormal growth rates in daily numbers of COVID-19 cases, based on these findings, considering both the slow vaccination rates in the early stages of vaccination and the need to vaccinate at least 60-80% of the population to gain herd immunity. Thus, we conclude that policy-makers should be more careful and take strict measures during vaccination by considering the risk of early relaxation in public.

**Supplementary material.** To view supplementary material for this article, please visit https://doi.org/10.1017/dmp.2023.147

**Acknowledgments.** The authors acknowledge Dr Mustafa Gokalp Ataman for sharing his expertise with authors in this research.

**Competing interests.** The authors declare no conflicts of interest.

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