Short communication

Evaluation of weekly COVID-19 vaccination and case data supports negative correlation between incidence and vaccination in German federal states and cities during 4th wave

Steffen Springer, Martin Kaatz, Michael Zieger *

SRH Wald-Klinikum Gera GmbH, Straße des Friedens, 122, Gera, 07548, Germany

ABSTRACT

Global efforts have been made to end the COVID-19 pandemic. Among other things, various vaccines against SARS-CoV-2, partly based on novel principles, have been developed internationally within a short time.

While initially the hardly available vaccines were distributed according to criteria according to defined priorities, in Germany, after the prioritization has been lifted, attempts are being made to provide as many people as possible with vaccinations.

The study examines the relationship between vaccination and incidence in 16 German federal states and city states using data from the Robert Koch Institute (RKI).

Clear trends became apparent, showing a negative correlation between the vaccination rate and the infection incidence. This indicates that during the 4th corona wave in Germany, the lower the incidence, the higher the vaccination rate.

1. Introduction

Since Li Wenliang (李文亮, 1986–2020) first drew attention to the novel respiratory disease that later became known as coronavirus disease 2019 (COVID-19) [1], many efforts vaccinations to bring the coronavirus pandemic under control. Vaccine candidates were developed by using different principles including mRNA, adenovirus vectors, protein subunits, and inactivated SARS CoV-2 [2,3,4].

COVID-19 vaccines approved in Germany were initially only available to a limited extent. The vaccination was therefore initially only offered to people who had a particularly high risk of severe or fatal courses of COVID-19 disease or who were either particularly exposed or had close contact with vulnerable groups at risk. This vaccination prioritization could be lifted in June 2021, as the supply of available vaccines in Germany increased.

The mRNA vaccine Comirnaty® (BioNTech / Pfizer) has been approved for children and adolescents aged 12 and over in the European Union since May 2021, Spikevax® (Moderna) since July 2021. During German vaccination campaign, the general vaccination recommendation for children and adolescents from the age of 12 for both mRNA vaccines was made by the Standing Committee on Vaccination at the Robert Koch Institute (RKI) in August 2020. The Standing Committee on Vaccination published its updated vaccination recommendations for Spikevax® (Moderna) in November and only recommended the vaccine for older age groups.

As part of the German vaccination campaign, many efforts were made to increase the vaccination rate in the population.

According to the Paul Ehrlich Institute, the German Federal Institute for Vaccines and Biomedical Medicines, the two mRNA vaccines from BioNTech/Pfizer and Moderna and the two vector vaccines from AstraZeneca and Janssen-Cilag (Johnson & Johnson) are approved in Germany. A sufficient vaccination was initially assumed here 1 (Janssen-Cilag) or 2 vaccinations. Booster vaccinations are recommended. There are discussions, hopes, and concerns in the population about the vaccination strategy [e.g. 5,6,7]. Despite all the efforts of the vaccination campaign, the vaccination rate in Germany has plateaued, in August 2021 at around 65 % [8].

The Federal Republic of Germany is a federal state consisting of 16 federal states and city states. The RKI, a German federal authority and research institution responsible for public health, disease control and prevention, collects and publishes relevant data on vaccinations and incidences during the pandemic. From July 2021, the incidences rose again and the RKI announced the start of the 4th wave in Germany ("Wöchentlicher Lagebericht des RKI

zur Coronavirus-Krankheit-2019 (COVID-19)", 19.08.2021; https://www.rki.de).

Data sources that are now accessible online provide a valuable basis for investigations into, among other things, infectious diseases such as COVID-19 [9]. In the study, the different vaccination rates and incidences during the 4th wave of the corona pandemic from late summer 2021, for which an already significant part of the population was sufficiently vaccinated, were examined for the German federal states and city states by using data from the RKI.

2. Data & methodology

In this study, data from German RKI's weekly status reports about COVID-19 ("Wöchentlicher Lagebericht des RKI zur Coronavirus-Krankheit-2019 (COVID-19)" from June 22nd to December 16th, 2021; https://www.rki.de) were used to evaluate the vaccination rates and incidences for the 16 German federal states and city states. The vaccination in differentiated age groups and vaccination rates by district could not be mapped with the available data.

To calculate the percentage vaccination rate, the number of two-fold vaccinated people was related to the respective number of inhabitants (data from Federal Statistical Office of Germany (https://www.destatis.de); accessed 12/2021). Persons with one dose of Janssen-Cilag vaccine or two vaccinations of the other vaccines at least 14 days ago are considered to be fully vaccinated. Although one vaccination is considered sufficient for a complete vaccination for the Janssen-Cilag vaccine, the Standing Committee on Vaccination recommends optimizing the basic vaccination with another dose of an mRNA vaccine after the first vaccination. In this study, the data from the RKI's digital vaccination rate monitoring were used. The number of persons indicated in the database of

the RKI as having been vaccinated twice was included in the evaluation of this study.

In this study, the incidence values I are shown as a function of the vaccination rates V for the federal states and cities. Linear regression was determined by Excel (Microsoft Office Professional Plus, 2019) according to the following formula for the linear regression graph:

$$I(V) = a * V + b$$

The incidence values are shown as a so-called 7-day incidence, which is the usual display in Germany. The 7-day incidence is an indicator for new infections confirmed by laboratory diagnostics in the past 7 days per 100,000 inhabitants. Values were obtained from RKI's weekly status reports.

As a first approximation and disregarding the complexity of the overall situation, extrapolation of the regression graphs yields a theoretical 7-day incidence (b) at a vaccination rate of zero (V = 0). In addition, a hypothetical vaccination rate can be determined that would be necessary to obtain a 7-day incidence of zero in the week under consideration:

$$V = -b/a$$

3. Results

As the examples in Fig. 1 show, when the vaccination rate is higher, the 7-day incidence, hereinafter incidence, is lower in the course of the examined period within the 4th wave of pandemics in Germany for vaccination rates well over 40%. The dots on the respective date symbolize the vaccination rate and incidence of a federal state or city. In Fig. 1, a negative relationship between incidence and vaccination coverage can be demonstrated for data in the course of the wave. The effect described is emphasized more
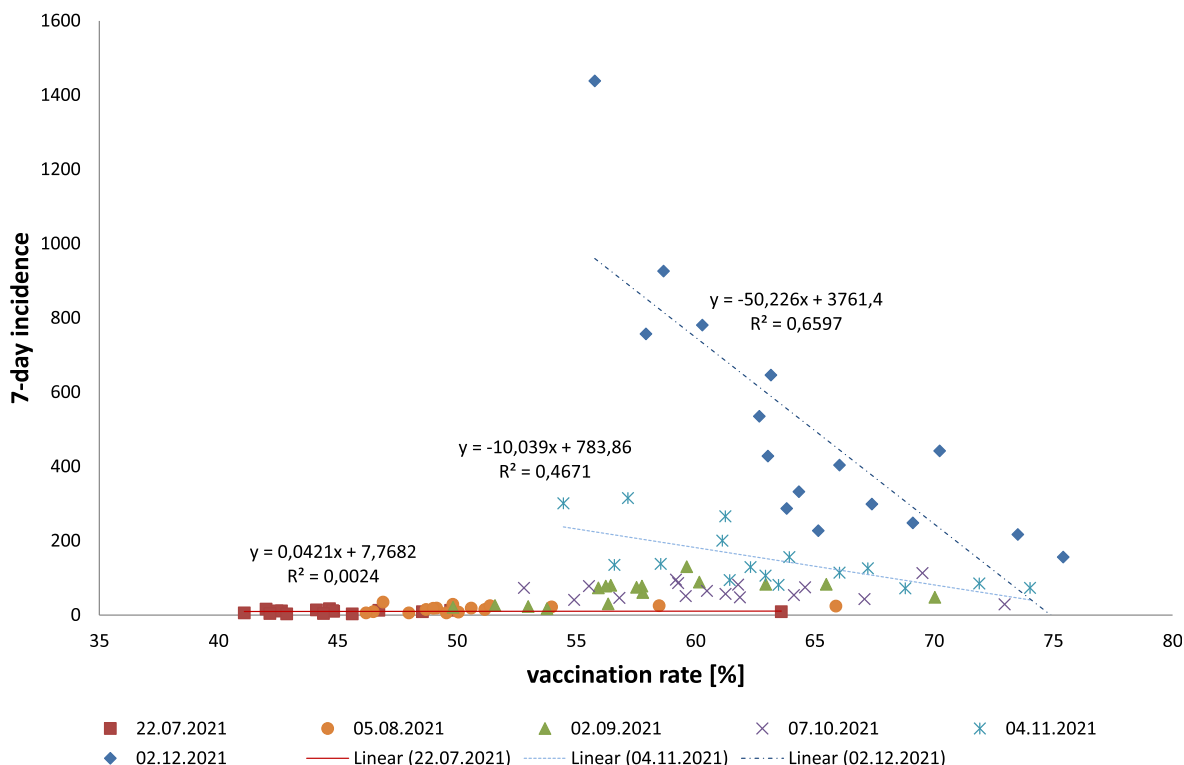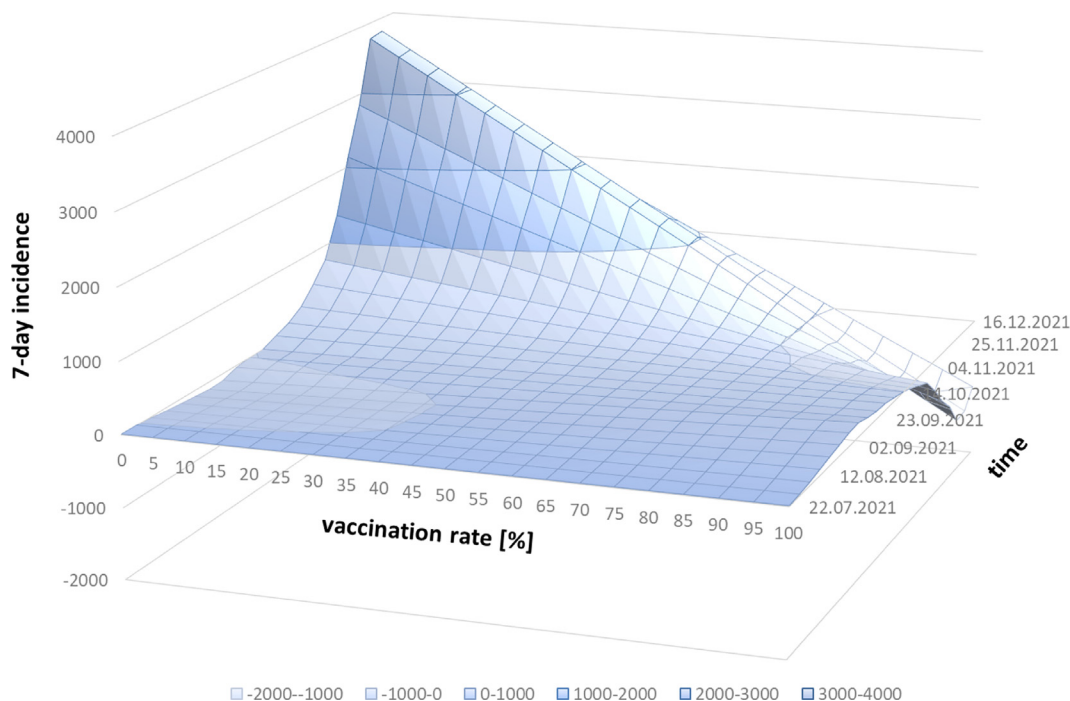

Fig. 1. Incidence values I (7–day incidence) are shown as a function of the vaccination rates V of twice vaccinated people in German federal states and city states as examples for weeks as indicated according to the German RKI's weekly status report (https://www.rki.de). Linear regression graphs are shown as examples for weeks as indicated.

Fig. 2. Linear regression graphs for 7-day incidence values I are shown as a function of the vaccination rates V of twice vaccinated people in German federal states and city states for weeks from June 22nd to December 16th, 2021, according to the German RKI's weekly status reports (https://www.rki.de).

clearly with increasing incidence from November to December 2021. In addition, an increased coefficient of determination (R^2) is specified for the examples shown.

Fig. 2 shows the linear regression graphs for incidence values as a function of the vaccination rates for twice vaccinated persons for the 16 German federal states and city states for the weeks examined from June 22nd to December 16th, 2021, according to the German RKI's weekly status reports. This illustrates the effect described for Fig. 1 using selected examples for the entire examined period from the end of July 2021. The regression graphs become steeper until December 2021 and show a negative correlation between incidence and vaccination rate. During December the graphs flatten again.

Fig. 3 shows the slope a in the linear regression graph as a function of the time course or the theoretically determined incidence at a vaccination rate of zero. This shows that with increasing incidence during the 4th wave, the slope becomes more negative over time until December (Fig. 3A). This means a steeper regression line that underlines the difference between federal states with high and low vaccination rates and the negative correlation between vaccination rate and incidence. This effect becomes more noticeable from the end of October, with an increase in the number of cases in the 4th wave (Fig. 3A). The effect is reduced during December, which is also underlined by the curves shown in Fig. 2.

A calculation for a hypothetical vaccination rate (V = - b / a) is shown as function of the theoretical incidence b at zero vaccination (Fig. 4). In the range of lower incidence values b, the necessary vaccination rates determined in the model are obviously unreliable. In the case of increased incidences above 500, a necessary vaccination rate of approx. 75% is set in this simplification (Fig. 4).

4. Discussion

The data within the 4th corona wave in Germany show a clear dependence of the incidence (7–day incidence) on the vaccination

rate. The incidence is strongly negatively correlated with the vaccination rate during the course of this wave. As expected, the data support the connection that a high vaccination rate is correlated with a lower incidence. This connection is plausible. But the real situation is much more complex.

This connection becomes clearer in the course of the 4th wave, with increasing the case numbers. In times of high incidence, a low vaccination rate has more negative effects. This can be seen in comparison with the summer months, when the graphs do not show a large negative increase that only develops over time. This fact, too, is obviously plausible, since a vaccination can only have a protective effect if the infection is prevalent. However, the data support these findings for the examined period within the 4th wave of pandemics in Germany in a situation with also higher current vaccination rates. Here, two variable parameters can only be compared to a limited extent. Initially, the incidences and vaccination rates were lower. Nevertheless, the relationship described is also very clear in the weeks from end of October with comparable vaccination rates and increasing incidence values.

However, this study has some limitations and more factors must be considered that make interpretation difficult. In addition to the unreported number of undetected infections, which influence both the number of cases and the number of potentially protected people, those who have recovered (and who may have been vaccinated once) in the population play a role in reducing the number of people at risk. The number of those vaccinated once was also neglected in the present approximation, but it does play a role in the incidence. According to the RKI, a certain amount of underreporting is also assumed when monitoring vaccination rates.

In addition, geographical, demographic and social aspects can influence the infection rate in the federal states, among other things [e.g. 10]. Here, for example, cross-border commuters and vacationers can play a role, which can contribute to the spread. Social issues, social contact frequency, and education may influence infections, access to medical care and vaccination, or testing frequency. Population structure, e.g. urban and rural distribution,

A

B
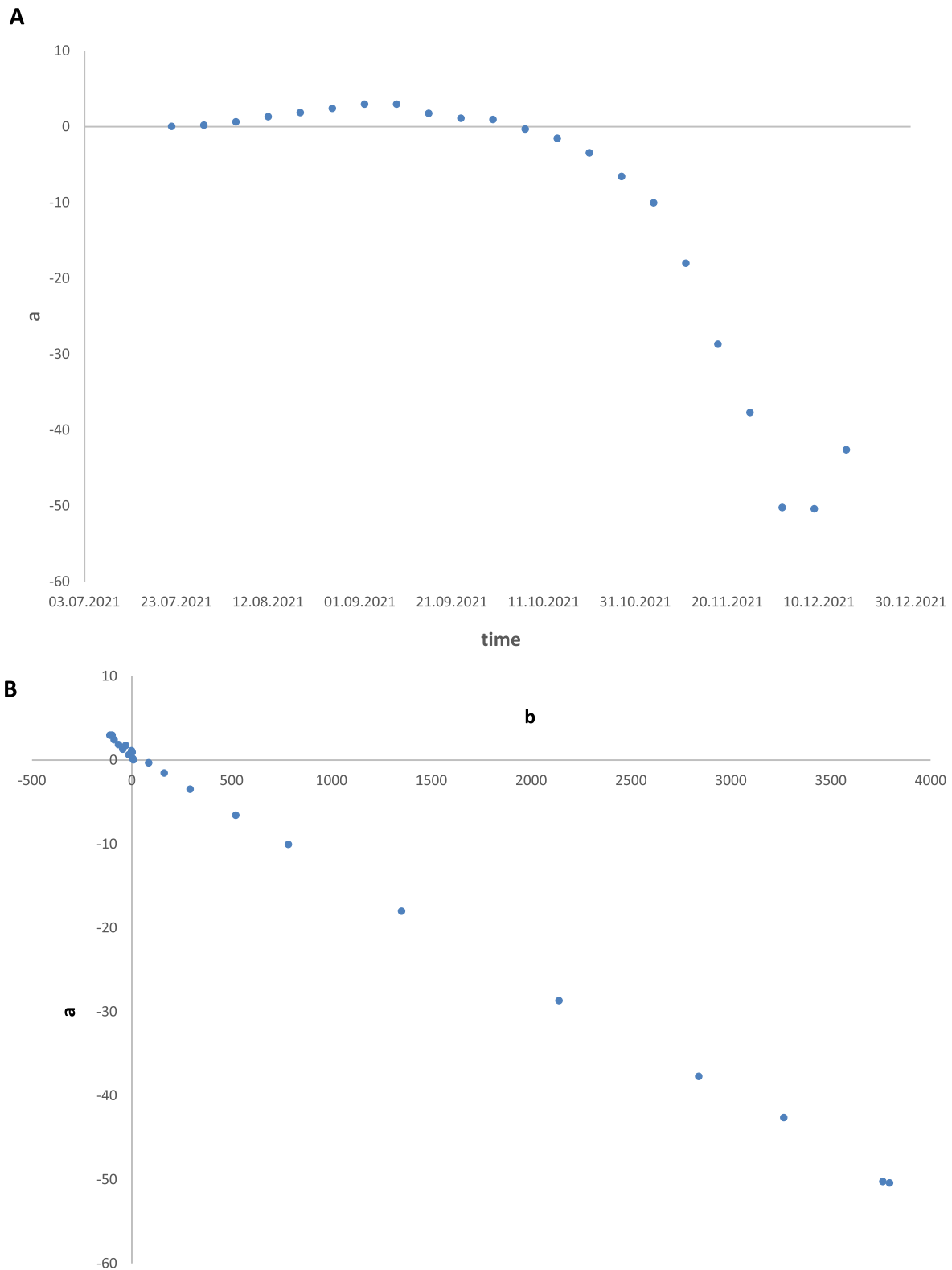
Fig. 3. The slope a of linear regression is shown as function of the time (A) and as function of the theoretical incidence (7–day incidence) b for theoretical zero vaccination rate (B).

number of inhabitants and population density were not considered in this first approach. The age structure creates an age-dependent risk and plays a role in the vaccination rate and the severity of the disease [11,12]. In addition, the necessary time between vaccination and the establishment of a protective effect should considered.

As part of a corresponding first simplification, the dependency for slope a on the theoretical incidence b at a vaccination rate of zero was determined. In this study, the slope of linear regression graphs is particularly steep (slope a has negative values according to the selected representation) for increased b values. This empha-
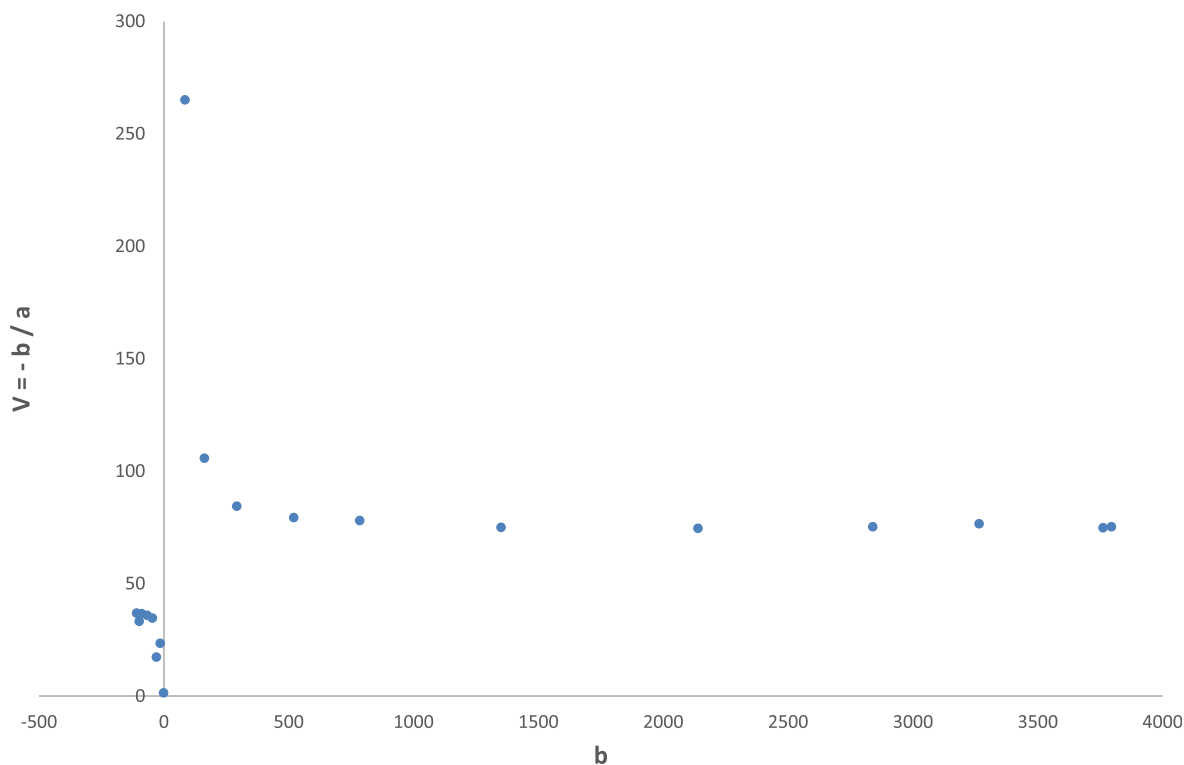
Fig. 4. Hypothetical vaccination rates (V = - b / a) that would be necessary to obtain a 7-day incidence of zero in the week under consideration is shown as a function of the 7-day incidence b at zero vaccination rate.

sizes the differences between federal states and cities with low and high vaccination rates in the incidence, which is reflected by the slope a of regression graph for a given week.

Likewise, values of ca. 75% could be determined as the theoretical aim of a vaccination rate during the current situation, for which an incidence of about zero (theoretically) would be expected if the regression line found is prolonged. With the decrease in the vaccination effect over time, different effectiveness of different vaccines, necessary booster vaccinations and new virus variants [e.g. 13], these remain very theoretical values, which, however, support other models that recommend a high vaccination rate and emphasize the important role of measures in controlling the disease [e.g. 14,15].

Further studies should examine the progress of vaccination in different age groups and also a representation of vaccination rates by district and for other countries.

5. Conclusions

Despite the limitations of the study, analysis of the available data showed a clear trend. This supports a negative correlation between incidence and vaccination in German federal states and cities during the 4th corona wave. And thus underlines the importance of adequate vaccination protection for control of the coronavirus.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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