Evaluation of the transmissibility of norovirus and the effectiveness of prevention and control measures for school in Jiangsu Province

Jing Wang  
Xiamen University

Jia Rui  
Xiamen University

Yuanzhao Zhu  
Nanjing Center for Disease Control and Prevention

Xiaohao Guo  
Xiamen University

Buasiyamu Abudunaibi  
Xiamen University

Benhua Zhao  
Xiamen University

Yanhua Su  
Xiamen University

Tianmu Chen  
13698665@qq.com  
Xiamen University

Research Article

Keywords: norovirus, transmissibility, total attack rate, peak incidence

Posted Date: March 9th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2559462/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

Objective: This study aims to estimate the transmissibility of norovirus outbreaks in schools by different transmission routes, evaluate the prevention and control effects of quarantine, school-closure and disinfection measures under different intervention intensities, and finally propose scientific and effective prevention and control suggestions.

Method: We selected 23 outbreaks of norovirus infectious diarrhea in Jiangsu Province’s school from 2012-2018, a SEIAQRW model was established, the effective reproduction number ($R_{eff}$) was used to assess the transmissibility of the outbreaks, the total attack rate (TAR) and peak incidence (PI) were calculated to evaluate the prevention and control effects of different intervention measures.

Results: The reproduction number of norovirus outbreaks in human-to-human route was 8.92 and in water or food-to-human route was 2.19, without intervention. When quarantine was implemented, the effect of reducing the total attack rate was average and the effect of reducing the peak incidence was better; When it took measures of school-closure or disinfection, the scale of the norovirus outbreaks decreased gradually as the intensity of intervention increased, and when the school-closure intensity or disinfection intensity reaches 90% or more, the total attack rate and the peak incidence reduced significantly.

Conclusion: Norovirus outbreaks are highly transmissible from human to human in schools. When a norovirus outbreak occurs, quarantine need to be supplemented with other interventions, and the implementation of high-intensity school-closure or disinfection of the external environment could effectively reduce the spread of the virus.

Introduction

Norovirus infectious diarrhea has attracted increasing attention in recent years. Globally, norovirus is a common cause of acute gastroenteritis, and the prevalence of norovirus in acute gastroenteritis cases is approximately 20% [1, 2]. Norovirus [3, 4], being a mutable RNA virus, does not provide long-term immunity after infection in the population, and there is no effective vaccine against norovirus [5]. In addition, the literature [6-8] shows that norovirus has a high viral excretion capacity and can cause disease at low doses. shows that noroviruses have a strong viral excretion capacity and can cause disease at low doses. Excreted pathogens can survive stably in various environments and are transmitted from person to person in various ways, such as direct interpersonal contact, ingestion of contaminated water or food, or exposure to contaminated environments. Therefore, once an infectious agent is present, it can easily cause transmission if not prevented and controlled in a timely manner.

Studies [9-11] have shown that outbreaks of norovirus have occurred in many provinces of China, mainly in school settings, which greatly affects the stability of education and the health of students. Several transmission dynamics models are now used to study the transmissibility of norovirus outbreaks in
schools and to assess the effectiveness of interventions, such as: Xu Yucheng\textsuperscript{[12]} used the SEIR model to evaluated the intervention effect of school-closure and disinfection measures for norovirus outbreaks in Shenzhen school premises. Chen Tianmu\textsuperscript{[13-15]} further studied on this basis and further divided infected individuals into symptomatic and asymptomatic individuals to construct the SEIAR model (susceptible-exposed-symptomatic-asymptomatic-recovered), and then evaluated the transmissibility of norovirus and the prevention and control effects of interventions. However, studies of norovirus epidemiological models are still relatively few, mainly focusing on norovirus outbreaks in the human-to-human transmission route and lacking effective intervention implementation efforts.

In this study, 23 small sites of norovirus outbreaks occurred in schools in Jiangsu Province from 2012 to 2018 were selected to assess the transmissibility of norovirus outbreaks in schools using the SEIAQRW dynamics model, and to study the intervention effects of isolation, school closure and disinfection under different intervention intensities, to provide a theoretical basis for rational selection of prevention and control measures.

**Methods**

**Research subjects**

Data on norovirus outbreaks in Jiangsu Province from 2012 to 2018 were collected, including the date of onset, number of cases, virus genotype, and place of occurrence. Preliminary screening criteria: these outbreaks occurred in schools, with clear norovirus genotypes, and the outbreak curves met the model fitting requirements. Then, using the transmission route as the main classification basis, the norovirus outbreaks in various types of places involved in different virus genotypes (based on VP1 sequences) were selected as the study objects, and a total of 23 norovirus outbreaks were obtained, including 19 outbreaks in the human-to-human route and 4 outbreaks in the water or food-to-human route.

**Construct a model for the spread of the norovirus outbreak**

The SEIAQRW model was constructed by combining the disease characteristics of norovirus, transmission routes and the implementation of prevention and control measures (Figure 1).

The model divided the population into six categories: susceptible ($S$), exposed ($E$), symptomatic ($I$), asymptomatic ($A$), quarantined ($Q$), recovered ($R$), and transmission medium ($W$). The system of differential equations is as follows:
In the above equation, $\frac{dS}{dt}$, $\frac{dE}{dt}$, $\frac{dI}{dt}$, $\frac{dA}{dt}$, $\frac{dQ}{dt}$, $\frac{dR}{dt}$ mean the rate of change in various populations at t-time, and $\frac{dW}{dt}$ is the rate of change in virus excretion and extinction in the environment at t-time. Parameters $\beta$, $\beta_W$, $k$, $\omega$, $\gamma$, $\gamma'$, $q$, $\mu$, $\mu'$ indicate the human-to-human transmission rate, water or food-to-human transmission rate, the transmissibility rate of the asymptomatic people relative to the symptomatic people, the incubation period, the latent period, the ratio of the asymptomatic people, the recovery rate of the symptomatic people, the recovery rate of the asymptomatic people, the quarantine rate of the symptomatic people, respectively.

A SEIAQRW model without interventions

Without intervention, the populations could only be S, E, I, A, R, parts. the default value of $q$ for this condition is 0. Since the W only has practical significance when the transmission route is water/food-to-human, if the selected norovirus outbreak is transmitted through the human-to-human transmission route, the default values of $\beta_W$, $\mu$, $\mu'$ and $\omega$ in the model under this condition are 0(Figure 1).

A SEIAQRW model for quarantine measure implemented

The population involved in the model is increased from that without intervention by Q. In a norovirus outbreak, quarantine measures are applied only to S because A is more difficult to detect. It is assumed that when S is detected, the authorities will take quarantine measures within half a day, and Q will recover at the same rate as S. When quarantine measures are taken, the proportion of S entering Q changes with Q, and the rest of the population changes as it would without intervention(Figure 1).

A SEIAQRW model for school-closure measure implemented
This study simulates the prevention and control effect after 3 days of school-closure. The populations involved in the model were the same as those in the no-intervention model. After taking the school-closure measure for the norovirus outbreaks that occurred in school, the $\beta$ in the model changed with the change in the average number of people exposed to each person per day after class-closure. The rest of the population changes as they did without intervention (Figure 1).

**A SEIAQRW model for disinfection measure implemented**

The populations involved in the model were the same as those in the no-intervention model. If the external environment disinfection measure is taken for the norovirus outbreaks, the $\beta$ in the model changes with the change in the probability of a single contact of the virus after disinfection. The rest of the population changed as they did without intervention (Figure 1).

**Parameter estimation**

A total of 21 parameters are involved in this study, their definition methods and values are shown in Table 1.

$\beta$, $\beta_W$ and $c$ are obtained by fitting the actual data with the model, and the time of peak incidence of the actual outbreak was the node to fit each outbreak to obtain the $\beta$ and $\beta_W$ before the node.

Studies have shown that the incubation period for norovirus infectious diarrhea is 12 to 48 hours \[^{16,17}\] , with an average duration of 1 to 3 days \[^{18-22}\] , after the outbreak of norovirus, the time to begin excreting the virus is 36 hours on average, and the exclusion time can last for about 26 days \[^{23}\] , and the survival time of the norovirus in the external environment is about 7 to 12 days \[^{24-32}\] . norovirus infectious diarrhea has a 30% share of asymptomatic\[^{23,33,34}\] , and the asymptomatic people can also excrete the virus from the outside environment, which is 0 to 25% more contagious than the symptomatic people\[^{35}\]. In addition, studies have shown that a person can contact an average of 15 people a day\[^{36}\] . In this study, the incubation period was 1 day, the latent period was 1 day, the disease course was 3 days, the infection period was 26 days, the proportion of asymptomatic people was 30%, the transmissibility rate of asymptomatic people relative to symptomatic people was 5%, the survival time of the virus in the external environment was 10 days, and the average contact of a person with 15 people per day was used to model this study. If quarantine measure is taken, this study assumes that cases will be sent to quarantine within half a day after they appear. That is, in the model, $\omega=1$, $\omega'=1$, $p=0.3$, $\gamma=1/3=0.3333$, $\gamma'=1/26=0.03846$, $\gamma''=1/0.5=2$, $k=0.05$, $=1/10=0.1$, $m=15$.

**Transmissibility and prevention and control effect evaluation indicators**

The transmissibility of norovirus can be quantified by the effective reproduction number $R_{eff}$, which is the average number of symptomatic people that a symptomatic person can cause during its infection period. In the model, the calculation formula for $R_{eff}$ can be simplified to:
In this study, the effect of various prevention and control measures was evaluated by the total attack rate (TAR) and the peak incidence (PI). The cumulative number of symptomatic people (n) and the maximum number of new symptomatic people per day (np) under various prevention and control measures of each outbreak can be obtained by model simulation, combined with the total number of exposed population (N), the total attack rate and the peak incidence can be calculated. The calculation formula is as follows:

\[
R_{eff} = \beta S \left( \frac{1 - p}{\gamma} + \frac{kp}{\gamma'} \right) + \beta' S \left[ \frac{\mu(1 - p)}{\gamma \varepsilon} + \frac{\mu' p}{\gamma' \varepsilon} \right]
\]

Sensitivity analysis

Since the parameters \( \omega, \omega', p, \gamma, \gamma', k \) were obtained through literatures, sensitivity analysis of these parameters was required for this study. In this study, the value range of these parameters was evenly divided into 10 equal parts for sensitivity analysis of the SEIAQRW model.

Model simulation and data processing methods

In this study, data entry and collecting using EXCEL2020, statistical analysis of related data using SPSS 26.0, the software MATLAB R2022a was used to simulate the model and plot, the parameter output of the model fitting was determined by least root mean square (LRMS). The differential equation solution uses the 4th-order Runge–Kutta method with a tolerance of 0.001.

Results

Epidemiological characteristics

We obtained epidemiological investigation reports of 23 norovirus outbreaks, which were divided into an early intervention group and a late intervention group according to whether the CDC intervened the day after the peak of the norovirus outbreak. 23 diarrheal outbreaks of norovirus infection and CDC interventions are shown below. (Figure 2). There was no statistically significant difference in norovirus transmissibility between the two groups. (Table 2)

Analysis for the transmissibility of Norovirus

For the 23 norovirus outbreaks in school, the average effective reproduction number in the human-to-human route was 8.92, with a 95% confidence interval (5.48, 12.37), and the average effective
reproduction number in the water or food-to-human route was 2.19, and the 95% confidence interval was (1.14, 3.24).

The 19 norovirus outbreaks of the human-to-human route, including 10 virus genotypes, the effective reproduction number (3.14 and 2.65) of GII.4 genotype (1 case) and GII.13 (1 case) were lower than the 95% confidence interval of the transmission route, the average effective reproduction number of GII.6 (2 cases) (15.27) was higher than the 95% confidence interval of the transmission route, and the effective reproduction number (32.95) of the GII.1 genotype (1 case) was much higher than the 95% confidence interval of the transmission route. The average $R_{eff}$ under different place was calculated for the 19 outbreaks, and the effective reproduction number of norovirus outbreaks in kindergarten, primary school, secondary school, Common Colleges and Secondary vocational school, and six-year school and nine-year school were 13.15 (2 cases), 14.6 (6 cases), 6.19 (5 cases), 4.55 (4 cases) and 3.25 (2 cases), respectively. The effective reproduction number of the four norovirus outbreaks in the water or food-to-human route all are within the 95% confidence interval. (Figure 3)

**Analysis for the effectiveness of prevention and control measures**

The total attack rates of norovirus outbreaks in schools without intervention, or with separate isolation, school suspension or disinfection measures under different intervention intensities were simulated as follows: The total attack rate without intervention for the person-to-person route was 70.11 (68.24, 70.15) %, and the total attack rate for some epidemics gradually decreased with increasing isolation coefficients after the implementation of isolation measures, and the decrease was more pronounced. In addition, the total attack rate obtained for most of the epidemic simulations was smaller, and when the isolation rate coeficient was 1, the total attack rate was 57.78 (8.69, 66.72) %. When the daily exposure coefficient (h) of the person was 0.1 or 0 after the school closure measures were implemented, the total attack rate obtained for each outbreak simulation was significantly reduced, with values of 3.87 (1.80, 22.07)% and 1.82 (0.56, 3.66)%, respectively. (Figure 4)

In the water or food-to-human route, the total attack rate without intervention was 60.92 (45.17, 68.61) %, and when isolation measures were implemented, the total attack rate for each epidemic gradually decreased as the isolation rate coefficient increased, and when the isolation coefficient was 1, the total attack rate was 35.28 (8.38, 62.74) %. When school closure measures were implemented, the simulated results for the total attack rate were the same as the change in the person-to-person route, with 33.02 (7.95, 46.78) % and 12.65 (2.73, 38.47) % when h was 0.1 or 0, respectively. There was no significant difference in the total attack rate between the two routes of transmission, simulated by class closure and disinfection measures at different intervention intensities. (Figure 4)

The simulated peak incidence was: The peak incidence for the person-to-person route without intervention was 14.37 (7.01, 19.95) %. The simulation results for each outbreak under the three interventions showed that the peak incidence tended to decrease gradually with increasing intervention intensity. If quarantine measures were implemented, the peak incidence was 1.73 (0.57, 7.05) % when the
quarantine coefficient was 1. When school closure measures were implemented and \( h \) was less than or equal to 0.3, the peak incidence of each epidemic simulation decreased significantly to 2.94 (0.54, 7.01)\%, 0.91 (0.54, 3.68)\%, 0.86 (0.28, 2.49)\% and 0.86 (0.28, 2.04)\%. (Figure 5)

In the water or food-to-human pathway, the peak incidence was 2.36 (0.87, 17.69)\% without interventions, and the change in peak incidence of outbreaks after the implementation of interventions was the same as in the human-to-human route. When quarantine measures were implemented and the quarantine coefficient was 1, the peak incidence was 1.44 (0.31, 8.74)\%. When quarantine measures were implemented and \( h \) was less than or equal to 0.3, the simulated peak incidence were 1.44 (0.31, 7.45)\%, 1.37 (0.30, 4.73), 1.32 (0.29, 3.00)\%, and 1.27 (0.28, 2.94)\%, respectively. There were no significant differences in peak incidence simulated between class closure and disinfection measures at different intervention intensities under both transmission routes. (Figure 5)

**Sensitivity analysis**

The simulated results show that the values of the parameters \( k, \omega, p, \gamma, \gamma' \), and \( \sigma \) set in the model have obvious differences in their value range, but there is no obvious difference in the simulation results of the parameter \( \omega' \) (Figure 6). It can be seen that the model has certain sensitivity to the parameters \( k, \omega, p, \gamma, \gamma' \), and the parameter \( \omega' \) is less sensitive in this model.

**Discussion**

In this study, the transmission routes of norovirus outbreaks were water or food to human GII genomes in the selection of study subjects, which validates the finding that noroviruses of GII genomes are more likely to be transmitted through water than GI genomes\[^{37}\], and is also consistent with the results of surveillance of noroviruses with predominantly GII genomes in sewage from another province (Guangdong Province) in China\[^{38}\]. The model simulation data without intervention in this study showed that norovirus outbreaks in school premises under both transmission routes could lead to symptoms in about 2/3 of the population. This is consistent with the extreme susceptibility of norovirus to cause transmission and suggests the importance of proposing effective prevention and control measures for norovirus outbreaks.

When calculating the effective reproduction number (\( R_{eff} \)) in school under different transmission routes, each outbreak between people had a high average effective reproduction number (8.92), and the effective reproduction number of outbreaks was much higher in kindergarten or elementary school than in the general population\[^{36}\], which may be due to the high density of people in schools, especially kindergartens or elementary schools, the high number of gathering activities, the high exposure, and the poor hygiene practices of young children. However, the mean effective reproduction number in the water or food-to-person route was smaller than in the person-to-person route and did not differ significantly compared to the general population. The results of the transmissibility study were the same as those calculated for norovirus outbreaks on cruise ships where the population is also highly dense and in
Besides, the effective reproduction number of 1 GII.1 genotype norovirus outbreak and 2 GII.6 genotype norovirus outbreaks were much higher than the general population. This indicates that the genotypes of these two noroviruses are more likely to cause transmission; on the other hand, there are many factors that affect the effective reproduction number, such as population aggregation, behavioral patterns, exposure to infectious agents, and climatic conditions, so the effective reproduction number may be overestimated due to the small number of outbreaks when calculating the effective reproduction number.

The simulated results of quarantine show that it can effectively reduce the peak incidence, the larger the quarantine rate coefficient, the better the effect. But it is less effective in preventing and controlling the total attack rate of the outbreak, and when the isolation rate coefficient is 1, the total attack rate of each outbreak in both transmission routes is reduced by less than 50%, which is consistent with the results of the study of Chen Tianmu implemented quarantine alone\[40\]. The reason for this analysis may be that isolation measures only target symptomatic individuals in an outbreak, but after norovirus transmission, up to 30% of asymptomatic individuals are infected and they are also contagious and the outbreak can continue to spread.

The results of the epidemic prevention and control effect when the class closure measures were taken for 3 days showed that. As the intensity increased, when the effect of class closure reached more than 90% (the daily exposure coefficient after class closure was less than or equal to 0.1), the total attack rate and the peak incidence of each epidemic were significantly lower than when there was no intervention, which indicated that timely large-scale class closure measures after norovirus outbreak could effectively reduce the size of the outbreak, which was consistent with the results of previous studies\[^{12,13}\]. This study focused only on epidemiological indicators of total attack rate and peak incidence, but the impact of economic, psychological, social, and educational stability factors should also be considered in the actual implementation of school-closure measures.

When disinfection measures were taken, there was no significant difference from class-closure measures, that is, when the disinfection effect reached 90% or more (the probability coefficient of single contact infection of the virus after disinfection is less than or equal to 0.1), the disinfection measures could effectively control the transmission of norovirus, which was consistent with the research results of Chen Tianmu \[^{13}\]. Therefore, it can be concluded that standardized disinfection of the external environment immediately after an outbreak in schools is a key measure to prevent and control the outbreak. Therefore, the following prevention and control recommendations are made for norovirus outbreaks in schools: after prompt isolation measures for all symptomatic personnel, mass class closures or standardized disinfection of the external environment should be facilitated immediately.

Outbreaks of norovirus in Jiangsu Province have persisted in recent years\[^{41,42}\], but the research on norovirus in Jiangsu Province has mostly focused on the classification of viruses\[^{15,41,43}\], and there is a lack of comprehensive evaluation studies on specific interventions in specific scenarios. In this study, based on our previous studies, we constructed intervention models of isolation, class closure and
disinfection measures for 23 norovirus outbreaks in Jiangsu Province based on the SEIAQRW model, and evaluated the effects of various interventions for norovirus outbreaks by setting different intervention intensities, which made up for the lack of research in Jiangsu Province only for epidemiological characteristics in recent years, and also enriched the research content of mathematical models in the field of norovirus research. These reflect the innovative significance of this study. In addition, the subjects selected for this study included multiple virus genotypes, different transmission routes, and multiple outbreak sites, so the results are more extrapolative than previous studies.

**Limitations**

The present study still has shortcomings. First, limited by model fitting, some parameters relied on literature and some relied on model fitting, but some of the outbreak data selected in this study were small, so there may be uncertainty in the fitted parameters, and the remaining parameters relied on literature, which may have an impact on the certainty and accuracy of the study. Second, the transmissibility analysis of the 23 norovirus outbreaks in this study was based on the timing of the CDC intervention, showing no significant difference between the two outbreaks, but norovirus infections with diarrhea usually have a short duration of illness at the time of the actual outbreak. Schools or parents generally take control measures such as treatment and home rest for symptomatic students earlier than CDC interventions; therefore, the number of norovirus outbreaks and the accuracy of outbreak investigations should be improved in follow-up studies to verify whether or how the timing of interventions affects the transmissibility of norovirus. Finally, this study only evaluated the prevention and control effects of some key individual interventions for norovirus outbreaks; other interventions, or the combined prevention and control effects of various interventions, have not been studied.

**Conclusion**

$R_{eff}$’s calculations show that norovirus is easily transmitted in schools (especially in human-to-human route), and it can eventually lead to more than two-thirds of the population becoming a case without intervention. Norovirus outbreaks’ prevention and control measures in schools, such as school-closure or the disinfection effect greater than 90%, can effectively reduce the total attack rate (TAR) and peak incidence (PI) of norovirus outbreak, and the implementation of isolation measures only has a good effect on the reduction of the peak incidence, but the three measures alone may not completely prevent the spread of norovirus. To better control the spread of norovirus in school premises, other prevention and control measures, such as widespread school closures or standardized disinfection, should be supplemented by timely isolation of all cases.

**Abbreviations**

Effective reproduction number ($R_{eff}$), total attack rate (TAR), peak incidence (PI), susceptible-exposed-symptomatic-recovered (SEIR), susceptible-exposed-symptomatic-asymptomatic-recovered (SEIAR),
susceptible-exposed-symptomatic-asymptomatic-recovered-water (SEIARW), susceptible-exposed-symptomatic-asymptomatic-quarantine-recovered-water (SEIAQRW).

**Declarations**

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

**Availability of data and materials**

The data that support the findings of this study are available from Jiangsu Provincial Center for Disease Control and Prevention, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. However, data are available from the authors upon reasonable request and with the permission of Ms. Zhu (Email: 1605852747@qq.com).

**Competing interests**

The authors declare that they have no competing interests.

**Funding**

This project was supported by National Key Research and Development Program of China (No. 2021YFC2301604) and Nanjing Important Science & Technology Specific Projects (2021-11005).

**Authors' contributions**

JW and TC designed this study. JR and YZ collected all required data. JW, JR, and TC contributed to the conception of the study. JW and XG designed the model and analyzed data. JW, YZ and BA calculated the transmissibility of this outbreak, JW, JR, BZ and YS draw all figures and tables. JW and JR were major contributors to write the manuscript. JW and JR contributed significantly to analysis and manuscript preparation. TC helped perform the analysis with constructive discussions. All authors read and approved the final manuscript.

**Acknowledgements**

Not applicable.

**References**


Table 1

Table 1 Model parameter definitions and valuation methods
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
<th>Value</th>
<th>Unit</th>
<th>Parameter source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>human-to-human transmit rate</td>
<td></td>
<td>$\text{km}^2 \cdot \text{day}^{-1}$</td>
<td>model fitting</td>
</tr>
<tr>
<td>$\beta_w$</td>
<td>water or food-to-human transmit rate</td>
<td></td>
<td>$\text{mL}^3 \cdot \text{virus}^{-1} \cdot \text{day}^{-1}$</td>
<td>model fitting</td>
</tr>
<tr>
<td>$k$</td>
<td>relative transmissibility rate of asymptomatic to symptomatic people</td>
<td>0.05</td>
<td>1</td>
<td>Literature $[35]$</td>
</tr>
<tr>
<td>$w$</td>
<td>incubation period</td>
<td>1</td>
<td>$\text{day}^{-1}$</td>
<td>literature $[16, 17]$</td>
</tr>
<tr>
<td>$w'$</td>
<td>latent period</td>
<td>1</td>
<td>$\text{day}^{-1}$</td>
<td>literature $[23]$</td>
</tr>
<tr>
<td>$p$</td>
<td>the ratio of the asymptomatic people</td>
<td>0.3</td>
<td>1</td>
<td>literature $[23, 33, 34]$</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>recovery rate of symptomatic people</td>
<td>0.3333</td>
<td>$\text{day}^{-1}$</td>
<td>literature $[18-22]$</td>
</tr>
<tr>
<td>$\gamma'$</td>
<td>recovery rate of asymptomatic people</td>
<td>0.03846</td>
<td>$\text{day}^{-1}$</td>
<td>literature $[23]$</td>
</tr>
<tr>
<td>$\gamma''$</td>
<td>quarantine rate of symptomatic people</td>
<td>2</td>
<td>$\text{day}^{-1}$</td>
<td>actual</td>
</tr>
<tr>
<td>$\mu$</td>
<td>virus excretion coefficient of the symptomatic people</td>
<td></td>
<td>$\text{virus}^{-1} \cdot \text{mL}^{-3} \cdot \text{day}^{-1} \cdot \text{km}^2 \cdot \text{person}^{-1}$</td>
<td>$c/\mu$</td>
</tr>
<tr>
<td>$\mu'$</td>
<td>virus excretion coefficient of the asymptomatic people</td>
<td></td>
<td>$\text{virus}^{-1} \cdot \text{mL}^{-3} \cdot \text{day}^{-1} \cdot \text{km}^2 \cdot \text{person}^{-1}$</td>
<td>$c/\mu'$</td>
</tr>
<tr>
<td>$c$</td>
<td>relative viral excretion ratio of asymptomatic to symptomatic people</td>
<td>1</td>
<td></td>
<td>model fitting</td>
</tr>
<tr>
<td></td>
<td>virus's extinction speed in water</td>
<td>0.1</td>
<td>$\text{day}^{-1}$</td>
<td>literature $[24-32]$</td>
</tr>
<tr>
<td>$q$</td>
<td>quarantine coefficient</td>
<td>0~1</td>
<td>1</td>
<td>actual</td>
</tr>
<tr>
<td>$e$</td>
<td>infection probability when exposure to the virus once</td>
<td>1</td>
<td></td>
<td>formula calculation</td>
</tr>
<tr>
<td>$m$</td>
<td>The average number of people a person can reach per day</td>
<td>15</td>
<td>$\text{person}$</td>
<td>literature $[36]$</td>
</tr>
<tr>
<td>$h$</td>
<td>The average number of people per person per day after class-closure</td>
<td>0~1</td>
<td>1</td>
<td>actual</td>
</tr>
<tr>
<td>$x$</td>
<td>infection probability when exposure to the virus once after disinfection</td>
<td>0~1</td>
<td>1</td>
<td>actual</td>
</tr>
</tbody>
</table>
Note: When calculating $e$, if $\beta \geq 1$, use the formula $e = \beta/m$; if $\beta < 1$, use the formula $e = 1 - (1-\beta)^{1/m}$.

**Figures**

Figure 1

Flowchart of the SEIAQRW model for norovirus outbreak
Figure 2

Epidemiological characteristics of 23 norovirus outbreaks
Figure 3

Calculation of Reff for various virus genotypes or places under two transmission routes

Note: P-P means human-to-human transmission route, W-P means water or food-to-human transmission route, and 1-5 in categories of places mean kindergarten, primary school, secondary school, Common Colleges and Secondary vocational school, and six-year school and nine-year school, respectively.
Figure 4

TAR simulation results under different interventions in two transmission routes

Note: When the abscissa is 0, it means that there is no intervention.
Figure 5

**PI simulation results under different interventions in two transmission routes**

Note: When the abscissa is 0, it means that there is no intervention.

Figure 6

**Sensitivity analysis results of SEAIQRW model**