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Short Communication

Little Risk of the COVID-19 Resurgence Caused by School Reopening in China (outside Hubei): A Statistical Probability Study -

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ABSTRACT

School reopening has not yet completely started in China where the COVID-19 outbreak has reached the ending stage, largely due to a great concern about COVID-19 infections on students. Here we explored a step-by-step procedure to quantitatively evaluate the risk of COVID-19 infections on students from infected teachers during school reopening. Results show that the probability of COVID-19 resurgence within one week on students of primary, middle, and high schools in China (outside Hubei) is extremely low (<0.2%) in typical provinces/cities that were most affected by COVID-19 epidemics in China. In some areas without newly confirmed cases in the past 14 days, the risk is zero. Such a probability can be updated daily and weekly based on the newly confirmed cases in the past 14 days. Our work provides guidance for local governments to make risk level-based policies for school reopening.

Keywords: COVID-19; COVID-19 resurgence; Risk assessment; School reopening

INTRODUCTION

The novel coronavirus diseases (COVID-19) outbreak is going on in China and has resulted in 80000 confirmed cases and over 3100 deaths as of 10 March 2020 [1]. Since March 11, China only reported 20 or less new cases, most of which are concentrated in Hubei Province and its capital Wuhan City, the epicenter of the outbreak. As such, China (outside Hubei) has entered a new stage of epidemic prevention and control coupled with a stepwise restoration of social and economic operations [2]. In particular, it is highly demanding to reopen schools because the delay of schooling time for approximately two months has substantially impacted more than 100 million families in China. Nevertheless, none of the schools has reopened so far across the country as of March 31, largely due to a great concern about the risk of COVID-19 infection on teenagers [3]. Here we show by statistical probability analysis that the risk of COVID-19 resurgence caused by school reopening is negligible.

METHODS

Our analysis is based on several assumptions as follows. First, a period of the past 14 days was set as a reference for risk assessment, given that the incubation period of COVID-19 ranges from 1-14 days with a mean of 5-6 days [2]. Second, the probability of infection in the coming week is proportional to the number of newly confirmed COVID-19 cases in the past 14 days. Third, only locally generated cases are counted while imported cases are omitted (Note: all travelers entering China are required a quarantine for 14 days [4]). Forth, only primary, middle and high schools were analyzed while colleges and universities were excluded because their students are from across the country (including Hubei Province and Wuhan City) but not solely locally living. Fifth, we assume that all students are healthy, given that only 0.9% of over 50000 COVID-19 cases in China are aged 0-9 years and 1.2% are 10-19 years [5,6]; as such, we simply focus on the potential transmission from teachers to students (or between teachers), excluding that from students to students or teachers. Last, we assume the secondary attack rate of the COVID-19 virus in schools is similar to that in households, ranging from 3-10% [2].

RESULTS

Under the above assumptions, there are no locally generated but only imported COVID-19 cases in most areas of China (except of Heilongjiang Province) since April 1, and therefore the risk of COVID-19 resurgence by school reopening is zero according to our model. To show our analysis as a proof of concept, we collected the data of population size, number of teachers and daily new COVID-19 cases from February 28 - March 12 in typical provinces/cities (refer

to Table S1) that have been most affected by the outbreaks and/or are most economically important in China. We then estimated the probability of COVID-19 transmission step by step, as detailed in table 1. Specifically, we first calculated the probability that at least one teacher has been infected and then estimated the probability of the infected teacher(s) to students or teachers (for detail, refer to table 1). We finalized the equation, in which new cases, population size, and teachers are incorporated to estimate the risk of COVID-19 transmissions from teachers to students in an area (Table 1).

Results show that the probability in all areas in the coming week (from 13-19 March) is extremely low (except Beijing), ranging from 0.01%-0.13% (Table 2). If the numbers of new confirmed cases in the past 14 days are zero in some areas (e.g., in Henan, Zhejiang, Jiangxi, Anhui, Guangzhou, and Shenzhen), then the risk is zero. If daily new cases as of 9 March were counted, then the probability of COVID-19 resurgence from 10-16 March would be a slightly higher, ranging from 0.01-0.37% (Table 2). The probability for Beijing is highest because of 10 new cases reported on 26 March (refer to table S1).

DISCUSSION

We previously revealed that the risk of COVID-19 resurgence caused by work resuming in China [7] was negligible, which is supported by the progression of COVID-19 epidemics in China after nationwide work resuming since mid-March [1]. Here our analyses suggest that the probability of COVID-19 resurgence regarding school reopening is low (all <0.5%) in all provinces/cities outside Hubei where daily new cases are sparse. Such probability can be updated daily or weekly based on the number of new cases in the past 14 days. In April and May, daily new cases in most provinces/cities we analyzed have become near-zero and thus the risk is nearly zero according to our calculation. Furthermore, the overall endanger of COVID-19 infection in students would be extremely low from the clinical point of view [8,9]. As a matter of fact, only a very small proportion of the COVID-19 cases aged under 19 years have developed severe (2.5%) or critical disease (0.2%) in China and only one death was from this age group among a total of 1023 deaths as reported by China CDC and WHO [2,3,6].

Our work may guide provincial governments to make risk level-based, differentiated control measures, by which societal activities, particularly school reopening, are effectively restored and the potential risk of COVID-19 resurgence is strictly controlled. During this process, governments always get ready to immediately react to any new COVID-19 cases or clusters. Besides, daily body temperature monitoring on teachers and students and inspecting their body status are necessary, and anyone who has symptoms of fever and cough

Table 1: Step-by-step calculation of the probability of COVID-19 resurgence caused by school reopening in China ^a.

Steps	Parameters	Guangdong Province ^a	Hunan Province ^a	equation for calculation
A	No. of new cases	2	1	
B	Population size	113,460,000	68,988,000	
C	No. of teachers	966,600	530,000	
D	Probability that a teacher is infected	0.000000013	0.000000010	D=A/B
E	Probability that all teachers are not infected everyday	0.9988	0.9995	E=(1-D)^C
F	Probability that all teachers are not infected within a week	0.9915168847	0.9961668259	F=E^7
G	Probability that there is at least one infected teacher within a week	0.0084831153	0.0038331741	G=1-F
H ^b	Probability (%) of the transmission from the infected teacher(s) to students under mild protective conditions	0.0848311531	0.0383317415	H=0.1*G
I	Probability (%) of the transmission from the infected teacher(s) to students under strict protective conditions ^b	0.0254493459	0.0114995224	I=0.03*G
Final equations: $\left(1 - \left(1 - \frac{A}{B}\right)^{7C}\right) * 0.1$ and $\left(1 - \left(1 - \frac{A}{B}\right)^{7C}\right) * 0.03$				
^a For simplicity, calculated was displayed in the case of Guangdong Province and Hunan Province. ^b The secondary attack rate of transmission from teachers to students or among teachers in schools was set as 10% and 3% under mild and strict protective conditions, respectively, by referring to the report of China-WHO Joint Mission [2].				

Table 2: Probability of COVID-19 resurgence after school reopening ^a.

Provinces /Cities	Total cases	Population (10 ⁴)	No. of teachers (10 ⁴)	13-19 March 2020		10-16 March 2020	
				New cases ^b	Probability (%) ^c	New cases ^b	Probability (%) ^c
Guangdong	1353	11346	96.7	2	0.03-0.08	3	0.04-0.13
Henan	1272	9605	99.3	0	0	1	0.02-0.05
Zhejiang	1215	5737	40.8	0	0	0	0
Hunan	1018	6898	53.0	1	0.01-0.04	2	0.02-0.08
Jiangxi	935	4647	42.2	0	0	1	0.01-0.05
Anhui	990	6323	48.7	0	0	1	0.01-0.04
Shandong	759	10047	85.1	3	0.04-0.13	2	0.03-0.08
Jiangsu	631	8050	60.3	0	0	0	0
Fujian	296	3973	32.5	0	0	2	0.02-0.08
Beijing	429	2153	12.3	3	0.03-0.09	13	0.11-0.37
Shanghai	344	2423	11.6	1	0.01-0.02	3	0.02-0.07
Guangzhou	347	1490	10.1	1	0.01-0.03	1	0.03-0.01
Shenzhen	419	1302	NA ^b	0	0	0	0
^a Steps for probability calculation are presented in table 1. ^b Daily new cases are shown in table S1. NA: not available. ^c The secondary attack rate was set as 3%-10% by referring to the estimates on family clusters [2].							

should be immediately isolated away from schools and subjected to further clinical diagnosis. Furthermore, the risk of COVID-19 resurgence on students can be further reduced by periodically (e.g., weekly, semi-monthly, or monthly) screening all the teachers with COVID testing kits to identify potentially infected ones, particularly those asymptomatic cases [10]. Meanwhile, all the teachers should be informed to avoid any unnecessary clustering activities that might increase their infection risk.

In our study, imported COVID-19 cases are subjectively excluded. Nevertheless, the risk of COVID-19 resurgence in China since April is largely from the imported COVID-19 cases [1], who are Chinese living outside China and attempting to come back due to the severe

outbreaks outside China. Such risk has been limited to be minimal in China through implementing strict prevention and control measures such as obligative COVID-19 testing and 14-day quarantine [1]. Another limitation of our study is the exclusion of asymptomatic COVID-19 cases, who are contagious but hidden in the populations [10,11], and lead to another major risk in China since April [1,12]. Recently, Wuhan City, the capital of Hubei Province and epicenter of the outbreaks in China between January and March, initiated a milestone plan of mass testing by which all the populations (around 10 million) will be screened by nucleic acid COVID-19 testing within 10 days [12] and the risk from asymptomatic COVID-19 cases would be largely eliminated.

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AUTHOR CONTRIBUTIONS

X.F. conceptually designed the research; C.L. collected data and performed analyses; T. Z. validated the statistical approach; X.F. wrote the manuscript.

Supplementary Files (Downloadable)

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