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Consequences of China's special send-down movement on infectious disease control in rural areas: a natural experiment

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ABSTRACT

Background: China's send-down movement in the 1960s and 1970s, as a natural experiment, provides a unique opportunity to investigate the relationship between peers' dissemination of health literacy, community health workers, and infectious disease control in areas with weak health systems and inadequate human resources. To address the lack of studies on the health effects of the send-down movement, this study examined the associations between prenatal exposure to the send-down movement and infectious diseases in China.
Methods: We analyzed 188,253 adults born in 1956–1977 with rural *hukou* who participated in the Second National Sample Survey on Disability in 2006 across 734 counties of China. Difference-in-difference models were used to detect the effect of the send-down movement on infectious diseases. Infectious diseases were ascertained by using the combination of self- or family members' reports and on-site medical diagnosis of disabilities attributed to infectious disease by experienced specialists. The density of the relocated urban sent-down youth or "sent-down youths" (SDYs) in each county defined the intensity variable of the send-down movement.
Results: Individuals in SDY-receiving areas with increased intensity of prenatal exposure to the send-down movement had a decreased probability of infectious diseases ($\beta = -0.0362$, 95% CI: 0.0591, -0.0133) after controlling for a set of regional and cohort characteristics. This association was stronger in counties with more prevalent infectious diseases prior to the send-down movement ($\beta = -0.0466$, 95% CI: 0.0884, -0.0048) than in those with less prevalence ($\beta = -0.0265$, 95% CI: 0.0429, -0.010). No substantial differences were found across sex-specific groups or by strictness of send-down movement implementation. On average, prenatal exposure to the send-down movement corresponded to a decrease in the probability of infectious diseases in rural areas by 19.70%.
Conclusions: For areas with weak health systems, strengthening community health workers and promoting health literacy may be two key points to address the burden of infectious diseases. Increasing education and primary health care through peer-to-peer dissemination may contribute to the reduction of infectious disease prevalence.

1. Introduction

In addition to COVID-19, other infectious diseases, such as tuberculosis and malaria, still remain global health challenges, with 8 million new cases of tuberculosis and 300–500 million new cases of malaria each year. Although some developing countries have eliminated a number of infectious diseases, the continued prevalence of infectious diseases in regions, such as Sub-Saharan Africa, challenges the achievement of the United Nation's 2030 Sustainable Development Goal target on communicable diseases. Since 1949, China has made large

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gains in infectious disease control, and was awarded polio-free and malaria-free certifications by the WHO in 2000 and 2021, respectively. The rapid progress in strengthening the dissemination of health literacy dissemination of health literacy and the primary health care system are key points for China's ability to combat infectious diseases(Jiang et al., 2020; Yu et al., 2018; L. Zhang & Wilson, 2012), which may provide lessons for other regions working towards eliminating communicable diseases.

In the late 1960s, China's government launched the "send-down movement," also known as the "rustication movement" or "going up to the mountains and down to the villages." While this policy was in effect, over 16 million sent-down youth (middle and high school graduates) were mandated to move from urban to rural areas (Cao, Chen, Pang, Zheng, & Nilsson, 2012; Y. Chen, Fan, Gu, & Zhou, 2020; Xie, Jiang, & Greenman, 2008). Prior research has reported both harmful and beneficial long-term effects of this movement on the sent-down youth who were sent, but there is evidence that, from the rural perspective, the arrival of those sent-down youth may have improved community health literacy in less developed regions and relieved shortages of healthcare workers (Cao et al., 2012; Y. Chen et al., 2020; Xie et al., 2008). This mass movement could have affected the incidence of infectious diseases in rural areas in the following ways: 1) Through community-based peer-to-peer education, the urban sent-down youth increased rural residents' knowledge of and ability to gather and process information on disease transmission mechanisms and vector control strategies; 2) Large proportions of sent-down youth were assigned to be counselors and teachers in countryside, introducing new values and healthy behaviors in school settings; 3) Some sent-down youth with basic medical and preventive techniques were assigned to be community health workers ("*barefoot doctors*"), guiding vaccination and prenatal health care programs and contributing to the construction of the Rural Cooperative Medical System (Yanhong, 2008.1.23. ; Yu et al., 2018).

The send-down movement provides a unique opportunity to investigate how such an unprecedented scale of resettlement of urban sent-down youth affected infectious diseases in rural areas of China with less education levels and poor health systems. This movement was launched in 1968 and declined after Mao Zedong's death in 1976. In 1977, these "sent-down youths" began leaving the countryside for urban areas, ending with a sharp decline in the number of sent-down youths still residing in rural areas in 1978 (Y. Chen et al., 2020). Specific cohorts born in rural areas during the sent-down movement may have had lasting health values, knowledge, and behaviors imparted to them by the sent-down youth, but those health effects are not well-studied.

To date, no studies have examined the effect of such a massive movement of sent-down youth on infectious disease control in rural areas. Treating the send-down movement of 1968–1976 as a natural experiment, this study used difference-in-difference models to capture the send-down movement's effect on the risk of infectious diseases, which may further elucidate the contribution of community health workers and peers' dissemination of health literacy to infectious disease control in poor areas and provide lessons for countries with increased burden of infectious diseases exacerbated by weak health systems and inadequate human resources. sent-down youth.

Our research revealed that prenatal exposure to the send-down movement corresponded to a decreased probability of infectious diseases. This association was particularly pronounced in counties with a higher prevalence of infectious diseases before the send-down movement, as evidenced by our heterogeneity analysis. On average, prenatal exposure to the send-down movement resulted in a 19.70% reduction in the probability of infectious diseases in rural areas. This study is structured as follows: Section 2 outlines the data and sample selection process. Section 4 presents the empirical findings, while Section 5 offers a discussion and conclusions.

2. Methods

2.1. Study design and data sources

This study used data from the Second National Sample Survey on Disability (SNSSD), which was a nationally representative investigation conducted from 1 April to 31 May 2006, covering 31 provinces, 734 counties or districts, 2980 towns or streets and 5964 communities or villages in China. The SNSSD collected information to characterize disabilities in China, including prevalence rates, causes and severities of disability, rehabilitation demands and medical needs, and living conditions of disability. This survey was derived by four-stage stratified random cluster sampling (counties, towns, interview sites, and households) with probability proportional to size. The SNSSD involved 2,526,145 participants with a 99.87% response rate, thus making up 0.19% of noninstitutionalized residents in China. Additional details about the SNSSD can be found elsewhere (Zheng et al., 2011).

We defined the treatment group as individuals born in 1968–1977 whose prenatal period overlapped with the arrival of sent-down youth. Thus, prenatal exposure was defined as maternal exposure (approximately 300 days from conception to delivery) for pregnancies during the send-down movement in 1968–1976. The control group was comprised of individuals born in 1956–1967, i.e., born prior to the send-down movement. We first excluded counties or districts in areas that were more likely to be districts that sent rather than received urban sent-down youth (including Beijing, Tianjin, Shanghai, and all districts in prefecture-level cities), and then excluded counties with missing information on the density of sent-down youth. Our final analytic sample was restricted to 188,253 adults with rural *hukou* born in 1956–1977, which the *hukou* refers to a household register. The flowchart of sample selection can be found in Fig. 1.

2.2. Measures

2.2.1. Infectious diseases

The SNSSD identified individuals with disabilities attributed to infectious diseases through self-reports by participants or their family members and on-site diagnosis by experienced medical specialists. Participants with functional limitations were identified by trained field interviewers with a structured five-item screening questionnaire developed according to the 'Guidelines and Principles for the Development of Disability Statistics.' This questionnaire was collected by face-to-face interviewing and was demonstrated to have high reliability (J. Zhang, 2010). Individuals who answered a positive response to the questionnaire were determined as likely to meet the criteria for functional limitations. Then, persons with a World Health Organization Disability Assessment Schedule, Version II (WHO DAS II) score $\geq$52 were diagnosed with functional limitations evaluated by experienced specialists (Field et al., 2000). Finally, experienced specialists diagnosed infectious diseases among persons who had disabilities attributed to any of the following diseases: poliomyelitis, tuberculosis, trachoma, maternal infection-related diseases (including infections with viral hepatitis, sexually transmitted diseases, etc.) and other infectious diseases related to hearing impairment (including rubella, measles, and epidemic cerebrospinal meningitis, etc.). The prevalence of disabilities attributed to infectious disease was used as a proxy for prevalence of infectious disease in the county.

2.2.2. Send-down intensity

As an obligatory and temporary policy, the send-down movement can be treated as a natural experiment to study how the arrival of new health knowledge and behaviors from urban areas influence infectious disease control in rural areas. During the send-down period, sent-down youth could not migrate or return to their sending areas because of stringent *hukou* restrictions and the mandatory send-down policy. At the end of the send-down movement, about 95% of sent-down youth and

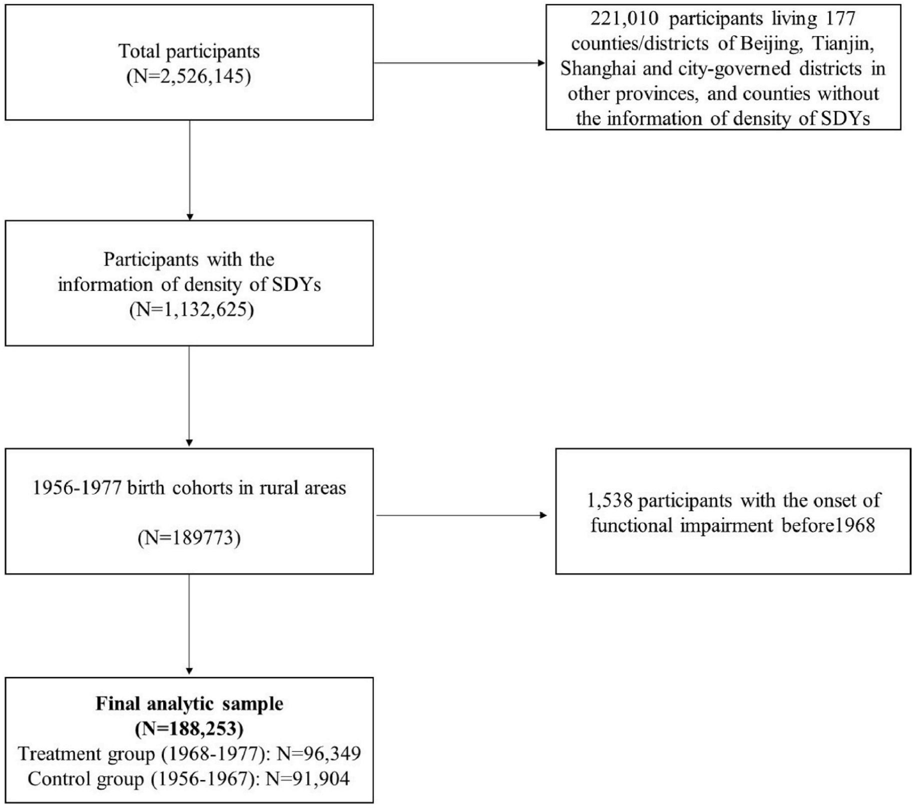

Fig. 1. Flowchart of the study sample
Note: SDYs = "sent-down youths".

their offspring left the receiving countryside, which reduces the possibility that sent-down youth (and their offspring), with better health literacy and behaviors, were counted as rural residents. Additionally, the send-down movement ended in 1978, which excludes the effects on infectious disease control by national immunization programs that were not initiated until 1978.

Send-down movement intensity was measured by the density of sent-down youth in each county obtained from Chen et al. (2020) (Y. Chen et al., 2020). The density of sent-down youth is proxied through the total number of sent-down youths during the send-down movement divided by the total number of persons in each county in 1964. Chen et al. (2020) collected these data from over 3000 local gazetteers and the 1964 census. A higher density of sent-down youth represents a higher magnitude of the send-down movement, which we hypothesized to have a greater effect on infectious disease control. We obtained the density of sent-down youth of 557 counties ranging from 0.10% to 18.43% with a mean of 2.34%, i.e., the average density of sent-down youth was 23.4 sent-down youth per 1000 locals during the send-down movement.

2.3. Control variables

Sex (male or female) and ethnicity (Han ethnicity or minority) were included as covariates. We also adjusted for the fixed effects of each county, interaction terms between province and cohort, and the interaction terms between infectious disease prevalence before the start of the send-down movement for each county and birth cohort to control for time-invariant traits of counties and unobservable differences in cohort trends. The prevalence of infectious diseases at the county-level was calculated as the prevalence of infectious diseases of the pre-send-down movement control group using the 2006 SNSSD database.

2.4. Statistical analysis

We used the cohort difference-in-differences (DID) method (Esther, 2001) to estimate the impact of the send-down movement on the probability of having a disability attributed to infectious diseases. The cohort difference-in-differences (DID) method is a statistical technique used to evaluate the causal effect of a treatment or intervention on an outcome variable, which is particularly useful when dealing with observational data. Two variations were estimated: variation in intensities of send-down movement exposure across regions and variation in intensities of send-down movement across birth cohorts. The effects of the send-down movement on each cohort could be separately estimated. The equation of linear probability models with the DID estimator is as follows:

$$Y_{ijk} = \alpha_0 + \Sigma_j\gamma_j\text{Cohort}_j + \Sigma_k\theta_k\text{sent-down youth}_k + \Sigma_j\Sigma_k\beta_{jk}\,(\text{Cohort}_j \times \text{sent-down youth}_k) + \eta X_{ijk} + \text{county}_k + \text{prov}_m \times \text{Cohort}_j + \Lambda_k \times \text{Cohort}_j + \varepsilon_{ijk}$$

where Y_{ijk} is the probability of infectious diseases for person i born in county k and year j. *sent-down youth*$_k$ is the density of sent-down youth in county k. Additionally, γ_j represents the cohort fixed effect, θ_k is the cohort fixed effect of the density of sent-down youth, and β_{jk} is the estimator of the send-down movement effect on the probability of infectious diseases. X_{ijk} denotes a series of control variables, including sex and ethnicity, $county_k$ is the country fixed effects, $prov_m \times Cohort_j$ represents the province-cohort fixed effects, $\Lambda_k \times Cohort_j$ is the interaction term between county-level infectious disease prevalence prior to the arrival of sent-down youth and cohort dummy variables, and ε_{ijk} denotes the standard error.

To test the robustness of our findings, we performed a heterogeneous analysis of prenatal exposure to send-down movement on the probability of infectious diseases by the subgroup of males vs. females and the subgroup of individuals in counties with more vs. less prevalent infectious diseases. Counties with "less prevalent" infectious diseases were defined as areas with county-level infectious disease prevalence (before the sent-down youth's arrival) at or below the median prevalence of 0.36%; counties with "more prevalent" infectious disease had county-level prevalence above that median. Additionally, we analyzed the effect of prenatal exposure to send-down movement and infectious diseases by the strictness of send-down movement, i.e., the degree to which the send-down policy was implemented. More strictly implemented send-down cohorts were the individuals born in 1968–1972, and less strictly implemented send-down cohorts were born in 1973–1977, following similar methods of a previous study (Ye, Zhu, & He, 2021).

This study used Stata 15 (Stata Corp, College Station, TX, USA) for data analysis.

3. Results

The characteristics of participants born in rural areas from 1956 to 1977 are presented in Table 1. The average (±SD) age of the 1956–1977 birth cohorts at the time of the survey was 39.05 (±6.03) years. A total of 49.69% were males, and 17.88% were of minority ethnicity. A total of 0.14% of the control group experienced disabilities attributed to infectious diseases, with an average age of 33.85 (±2.79) years, whereas 0.36% of the 1968–1977 treatment group experienced disabilities attributed to infectious diseases, with an average age of 44.01 (±3.61) years. Among the control group, 49.33% were males, and among the treatment group 50.06% were males. The proportions of minority ethnicity in the control and treatment groups were 19.25% and 16.58%, respectively. Although a higher prevalence of infectious diseases was initially observed in the treatment group as compared to the control group, this unadjusted calculation cannot distinguish whether the difference is attributed to effects of sent-down youth or of other unobserved regional or cohort characteristics.

Table 2 presents the adjusted DID regression coefficients of send-down movement on the probability of having a disability attributed to infectious diseases. Individuals who were born in areas that received sent-down youth and with greater intensity of the send-down movement had a lower probability of infectious diseases (β = −0.0362, 95% CI: 0.0591, −0.0133). Given that the average density of sent-down youth was 2.34% and the prevalence of infectious diseases in rural areas before the send-down movement was 0.43%, exposure to the send-down movement during the prenatal period decreased the prevalence of infectious diseases in rural areas by 19.70% (=(2.34% × 0.0362)/0.43% × 100).

Results from heterogeneous analyses showed that the send-down movement substantially decreased the probability of infectious diseases in both male and female subgroups, with coefficients of −0.0409 (95% CI: 0.0811, −0.0006) and −0.0315 (95% CI: 0.0562, −0.0067), respectively. However, the interaction terms of sex and the association of prenatal exposure to the send-down movement with infectious diseases were not substantial (see Table 3 and eTable 4). There also appeared to be a heterogeneous effect of the send-down movement on infectious disease by prevalence of county-level infectious diseases: effects of send-down movement were larger for individuals in counties with more prevalent infectious disease (β = −0.0466, 95% CI: 0.0884, −0.0048) as compared to counties with less prevalent infectious disease (β = −0.0265, 95% CI: 0.0429, −0.0100), and this difference was substantial (see Table 3 and eTable 4). Additionally, the effects of the send-down movement were observed in cohorts with more strictly implemented send-down movement (β = −0.0372, 95% CI: 0.0626, −0.0119) and less strictly implemented send-down movement (β = −0.0311, 95% CI: 0.0581, −0.0034), but the difference between these two groups was not substantial (see Table 3 and eTable 4).

Table 1
Characteristics of participants born in rural areas from 1956 to 1977, the Second National Sample Survey on Disability in 2006 (N = 188,253).

Characteristics	Total (1956–1977) (N = 188,253)	Control group (1956–1967) (N = 91,904)	Treatment group (1968–1977) (N = 96,349)
Infectious diseases, n (%)	466(0.25)	134(0.14)	332(0.36)
Age, mean (SD)	39.05(6.03)	33.85(2.79)	44.01(3.61)
Male, n (%)	93,540(49.69)	47,530(49.33)	46,010(50.06)
Minority ethnic, n (%)	33,666(17.88)	17,696(19.25)	15,970(16.58)

Table 2
The effect of prenatal exposure to send-down movement on the probability of infectious diseases, based on linear probability regression models with difference-in-difference estimators, the Second National Sample Survey on Disability in 2006 (N = 188,253).

Characteristics	Infectious diseases
Density of received SDYs	0.0086(-0.008, 0.0252)
Affected cohorts	0.0030(0.0022, 0.0038)
Density of received SDYs × affected cohorts	−0.0362(-0.0591, −0.0133)
Male sex	0.0010(0.0005, 0.0014)
Minority ethnic	0.0003(-0.0005, 0.0011)

Notes: All models adjusted for the county fix effect, province-cohort fix effect, base infectious diseases prevalence × cohort fix effect.

A placebo test was conducted as a sensitivity analysis. The control group (1956–1967 birth cohorts) was bisected into control cohorts (1956–1961) and placebo-treated cohorts (1962–1967). Our results show the placebo test results with no substantial differences, which supports the equal-trend assumption in our DID analyses (eTable 2).

4. Discussion

By considering the mandatory send-down movement of 1967–1978 in China as a natural experiment, we studied the effects of sent-down youth on infectious diseases in rural counties. To our knowledge, this study is the first to examine the health consequences of the send-down movement in the rural areas receiving urban sent-down youth. We estimated that prenatal exposure to the send-down movement corresponded to a decrease in the probability of infectious diseases in rural areas on average by 19.70%, and this send-down movement effect on infectious disease control was stronger in counties with more prevalent infectious diseases than in counties with less prevalence. While the send-down movement had wide-ranging consequences on the sent-down youth who were moved from urban to rural areas, these sent-down youth may have served as an important bridge connecting urban and rural areas, leading to improvements in the rural areas receiving them. The sent-down youth could have contributed to health improvements in their receiving countryside counties by introducing urban techniques, values, and behaviors, while also helping rural residents understand, apply, analyze, and disseminate health information or health services. This historical event provides a unique opportunity to investigate the contribution of human capital accumulation and health literacy transmission to infectious disease control in rural areas.

Two mechanisms may explain the effect of prenatal exposure to the send-down movement on infectious disease control. First, sent-down youth were important in helping rural women ensure adequate nutrition intake and learn coping strategies for stressful relationships during pregnancy, which are crucial to the prevention of infectious diseases and subsequent congenital complications that could lead to disabilities (J. Chen et al., 2021; Lisker-Melman et al., 2020; Marques, O'Connor, Roth, Susser, & Bjørke-Monsen, 2013; Massey, Rising, & Ickovics, 2006; Nielsen, Hansen, Simonsen, & Hviid, 2011; Robinson et al., 2021). Sent-down youth with well-educated backgrounds brought urban knowledge to rural areas. During the period of the send-down movement, the average number of persons per county with secondary school educational attainment increased from 3.3 in 1968 to 80.8 in 1976. Additionally, sent-down youth introduced techniques of midwifery, maternal, and child care to rural areas, thus improving prenatal health

Table 3
Heterogeneous effect of prenatal exposure to send-down movement on the probability of infectious diseases, based on linear probability regression models with difference-in-difference estimators, the Second National Sample Survey on Disability in 2006.

Characteristics	Male (N = 93540)	Female (N = 94713)	Less prevalent infectious diseases counties (N = 93810)	More prevalent infectious diseases counties (N = 94443)	More strictly send-down (1968–1972 cohorts) (N = 144,617)	Less strictly send-down (1973–1977 cohorts) (N = 134,462)
Density of received SDYs	0.0073 (-0.026,0.0406)	0.0101 (-0.0063,0.0264)	0.0021(-0.0051,0.0093)	0.0149(-0.0115,0.0414)	0.0086(-0.009,0.0259)	0.0062 (-0.0172,0.0297)
Affected cohorts	0.0035 (0.0023,0.0047)	0.0025 (0.0015,0.0034)	0.0031(0.0022,0.0039)	0.0029(0.0015,0.0044)	0.0032 (0.0021,0.0041)	0.0004 (-0.0005,0.0014)
Density of received SDYs × affected cohorts	−0.0409(-0.0811,-0.0006)	−0.0315(-0.0562,-0.0067)	−0.0265(-0.0429,-0.010)	−0.0466(-0.0884,-0.0048)	−0.0390(-0.0660,-0.0118)	−0.0311(-0.0581,-0.0034)
Male sex	/	/	0.0006(0.0000,0.0012)	0.0013(0.0006,0.0020)	0.0009 (0.0004,0.0014)	0.0008 (0.0001,0.0014)
Minority ethnic	0.0005 (-0.0006,0.0017)	0.0002 (-0.0006,0.0009)	0.0003(-0.0007,0.0012)	0.0004(-0.0008,0.0016)	0.0004 (-0.0004,0.0012)	0.0002 (-0.0007,0.0012)

Notes: All models adjusted for the county fix effect, province-cohort fix effect, base infectious diseases prevalence × cohort fix effect.

care conditions. Healthy pregnancies, especially in addressing malnutrition and avoiding prenatal stress, lead to healthy development and growth, which may further decrease the risk of infectious diseases in offspring (Marques et al., 2013; Nielsen et al., 2011). Second, sent-down youth assigned as community health workers ("*barefoot doctors*") played an important role in health system development and infectious disease prevention. Generally, these community health workers undertook various tasks, including case management of maternal and childhood illnesses, promotion of healthy behaviors, and delivery of preventive interventions of communities (A et al.). In China, "barefoot doctors" reached almost every village, devoting much time to preventive medicine, and eventually became the backbone of rural cooperative medical services (C; L & H). They largely alleviated vaccine shortage conditions prior to national immunization campaigns and enhanced access to health care in rural areas (Y. Chen et al., 2020; Gu, 2009; Rosenthal & Greiner, 1982). While China experienced an acute shortage of health workers and vaccines during the 1960s and 1970s, "barefoot doctors" were responsible for transporting vaccines from hospitals in urban areas to their respective villages, which promoted infectious disease control (Li, 2015).

As additional sensitivity analyses, we compared the impacts of the send-down movement on infectious diseases across exposures during different developmental stages ranging from prenatal to early adulthood (see eTable 3). We found that the send-down movement exposure effect was decreased in the infant stage, and no substantial associations were found between send-down movement exposure during preschool, teenage, or early adulthood stages and infectious diseases. Although early childhood is a crucial period for the prevention of infectious diseases (Gurgel & Correia, 2007; Jung, Min, Kim, & Min, 2021), the prenatal stage, including prenatal care and health education, may be the most important stage for the prevention of disabilities caused by infectious diseases. However, these findings may have been biased in that most of the infectious diseases contributing to the disabilities we studied (e.g., poliomyelitis, cerebrospinal meningitis) were infections that present in newborn or early childhood stages (Khandaker, Stochl, Zammit, Lewis, & Jones, 2015; Schwoebel et al., 1992).

As another check for robustness, we included the additional years of 1979–1988 and used DID models to separately estimate the effects of send-down movement prenatal exposure on each year's cohort compared with the control group of 1951–1955 birth cohorts (see eFig. 1). Our findings showed that no heterogeneous effect existed in cohorts prior to the send-down movement relative to the density of sent-down youth, except for the rising trend in the 1961 birth cohort, which was possibly impacted by the Great Famine of 1959–1961. The Great Famine could have increased risk of infectious diseases (Cheng et al., 2020). Our analysis with the exclusion of the 1962 cohort indicated that the findings in this study are robust after the exclusion of potential immediate impacts of the Great Famine (see eTable 1). Furthermore, we found that the coefficients gradually decreased after the start of the send-down movement in general, with later cohorts having a lower probability of infectious diseases with increasing density of sent-down youth. The lasting effects of the send-down movement or the later impacts of expanded immunization programs may have contributed to the continuous decline of infectious diseases after the movement ended in 1978.

Several limitations exist in this study. First, this study could not separate the confounding age effect from the cohort effect in a cross-sectional dataset based on cohort DID strategy identification. Although most of the infectious diseases involved in this study presented through infection in early childhood and the confounding age effect can be alleviated to some extent, our results should be interpreted with caution. Second, other historical events may have influenced the distribution of our outcome. For instance, as previously mentioned, the Great Famine prior to the send-down movement may have created conditions that increased the risk of infectious diseases, thus leading to an overestimation of the effect of sent-down youth on infectious disease control. The Great Famine also resulted in a tragic loss of life, and mortality rates could have varied by county, resulting in potential differential censoring rates before individuals could be surveyed. Further studies with more granular and longitudinal data are warranted to confirm our results. Third, while we restricted our study sample to individuals with rural *hukou*, unobserved migration may affect our results. Given *hukou* system restrictions and the strict regulations on rural-to-urban migration, the living place at the time of survey was used to identify an individual's birthplace at the county-level. However, the estimated density of sent-down youth for an individual's prenatal exposure may not reflect the true density if the individual moved, or if the density was not uniform within a county. Forth, the infectious diseases examined in this study were identified based solely on functional impairments associated with those diseases due to no exclusion for people with disability, which could result in an underestimation of both the prevalence of infectious diseases and the impact of sent-down youth on infectious disease control.

5. Conclusions

In conclusion, our study found a beneficial effect of prenatal exposure to the send-down movement on infectious disease control in rural Chinese counties. While this study does not suggest mandated relocation per se, community health activities and education from sent-down youth may have led to improved infectious disease prevention in rural areas. Future studies could evaluate other community health outcomes from the send-down movement and examine potential mechanisms to health promotion in rural areas. Our findings also highlight the potential of factors such as human resource accumulation, community health workers, and peers' dissemination of health literacy to improve infectious disease control in poor areas. These factors may be helpful to improve the ability of countries with weak health systems and an inadequate supply of health workers to combat the burden of infectious disease.

Ethics approval and consent to participate

This survey was conducted in all provinces by the Leading Group of the National Sample Survey on Disability and the National Bureau of Statistics with approval by the State Council of China. The study protocol of SNSSD was approved by the China State Council (No. 20051104) and conducted in accordance with the legal framework of the Statistical Law of the People's Republic (version 1996) of China. All participants provided informed consent to the government of China.

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Authors' contributions

Yanan Luo: drafting the manuscript, data analysis, interpretation and revision of article. Ye Xin, Yiran Wang, Yunduo Liu and Richard Liang: revision of article. Ping He and Xiaoying Zheng: study concept and design and critical revision of article for important intellectual content.

Consent for publication

All authors gave final approval of the version to be published.

Availability of data and material

N/A.

Declaration of competing interest

No competing interests in this study.

Data availability

The data that has been used is confidential.

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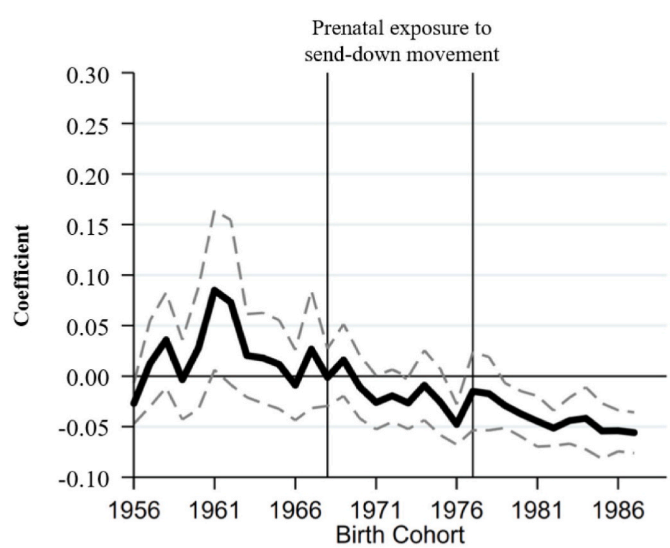
List of abbreviations

SNSSD Data from the Second National Sample Survey on Disability
DID difference-in-differences
WHO DAS II World Health Organization Disability Assessment Schedule, Version II

Appendix



eFigure 1. Effect of prenatal exposure to send-down movement on the probability of infectious diseases of different cohorts, based on linear probability regression with difference-in-difference estimators, the Second National Sample Survey on Disability in 2006. Gray dashed lines indicate 95% confidence interval.

eTable 1
The effect of prenatal exposure to send-down movement on the probability of infectious diseases by different control groups, based on linear probability regression models with difference-in-difference estimators, the Second National Sample Survey on Disability in 2006 (N = 188,253)

Characteristics	Cohort (1968–1977) versus cohort (1956–1960)	Cohort (1968–1977) versus cohort (1962–1967)
Density of received SDYs	−0.0007(-0.0110, 0.0096)	0.0132(-0.0172, 0.0435)
Affected cohorts	0.0033(0.0025,0.0041)	0.0026(0.0017, 0.0036)
Density of received SDYs × affected cohorts	−0.0272(-0.0476, −0.0067)	−0.0410(-0.0740, −0.0078)
Male sex	0.0012(0.0007, 0.0018)	0.0012(0.0006, 0.0018)
Minority ethnic	0.0004(-0.0006, 0.0014)	0.0004(-0.0006,0.0014)

Notes: All models adjusted for the county fix effect, province-cohort fix effect, base infectious diseases prevalence × cohort fix effect.

eTable 2
Placebo test of the effect of prenatal exposure to send-down movement on the probability of infectious diseases, based on linear probability regression with difference-in-difference estimators, the Second National Sample Survey on Disability in 2006

Dependent variables	Placebo (1956–1961) versus (1962–1967)
Density of received SDYs	0.0002(-0.0108,0.0112)
Affected cohorts (placebo)	0.0006(-0.0002,0.0015)
Density of received SDYs × affected cohorts (placebo)	0.0158(-0.0203,0.0520)
Male sex	0.0005(0.0000,0.0010)
Minority ethnic	0.0006(-0.0002,0.0013)

Notes: All models adjusted for the county fix effect, province-cohort fix effect, base infectious diseases prevalence × cohort fix effect.

eTable 3
The effect of prenatal exposure to send-down movement on the probability of infectious diseases by overlap with development stages, based on linear probability regression with difference-in-difference estimators, the Second National Sample Survey on Disability in 2006

Development stage (age during send-down movement period)	Sex and ethnic adjusted model
Prenatal (0 year)	
Density of received SDYs	0.0086(-0.0080, 0.0252)
Affected cohorts	0.0030(0.0022, 0.0038)
Density of received SDYs × Affected cohorts	−0.0362(-0.0591, −0.0133)
Infant (0–2 years)	
Density of received SDYs	0.0039(-0.0092,0.0170)
Affected cohorts	0.0025(0.0018,0.0032)
Density of received SDYs × Affected cohorts	−0.0201(-0.0364, −0.0039)
Preschool (3–5 years)	
Density of received SDYs	0.0077(-0.0049,0.0204)
Affected cohorts	0.0029(0.0020,0.0039)
Density of received SDYs × Affected cohorts	−0.0125(-0.0429,0.0178)
Mild-childhood (6–11 years)	
Density of received SDYs	−0.0009(-0.0132,0.0114)
Affected cohorts	0.0023(0.0014,0.0032)
Density of received SDYs × Affected cohorts	0.0077(-0.0211,0.0364)
Young teen (12–14 years)	
Density of received SDYs	0.0172(-0.005,0.0395)
Affected cohorts	0.0026(0.0016,0.0036)
Density of received SDYs × Affected cohorts	−0.0188(-0.0505,0.0129)
Teenage (15–17 years)	
Density of received SDYs	−0.0012(-0.0236,0.0213)
Affected cohorts	0.0000(-0.0011,0.0010)
Density of received SDYs × Affected cohorts	0.0060(-0.0255,0.0376)
Adult (18–30 years)	
Density of received SDYs	−0.0100(-0.0596,0.0397)
Affected cohorts	−0.0005(-0.0020,0.0009)
Density of received SDYs × Affected cohorts	0.0092(-0.0374,0.0557)

Notes: All models adjusted for the county fix effect, province-cohort fix effect, base infectious diseases prevalence × cohort fix effect.

eTable 4
Heterogeneous effect of prenatal exposure to send-down movement on the probability of infectious diseases, based on linear probability regression models with difference-in-difference estimators, the Second National Sample Survey on Disability in 2006 (N = 188,253)

Characteristics	Sex	More/less prevalent infectious diseases counties	More/less strictly implemented send-down
Density of received SDYs	0.0067(-0.0093,0.0228)	0.0041(-0.0052, 0.0135)	−0.0444(-0.0870, −0.0018)
Affected cohorts	0.0029(0.0021,0.0037)	0.0028(0.0020, 0.0036)	

(continued on next page)

eTable 4 (*continued*)

Characteristics	Sex	More/less prevalent infectious diseases counties	More/less strictly implemented send-down
DID (Density of received SDYs × affected cohorts)	−0.0382(-0.0593, −0.0172)	0.2514(0.1795, 0.3234)	
DID × male sex	0.0073(-0.0151,0.0297)		
DID × more prevalent infectious diseases counties		−1.8220(-2.9310, −0.7130)	
Cohort exposure during prenatal period			
More strictly implemented send-down cohorts			1
Less strictly implemented send-down cohorts			−0.0020(-0.0042,0.0002)
Non-exposure			−0.0001(-0.0022, 0.0021)
Cohort exposure during prenatal period × density of received SDYs			
More strictly implemented send-down cohorts × density of received SDYs			1
Less strictly implemented send-down cohorts × density of received SDYs			0.0185(-0.0220,0.0590)
Non-exposure × density of received SDYs			0.0658(0.0209,0.1107)

Notes: All models adjusted for the sex, ethnicity, county fix effect, province-cohort fix effect, base infectious diseases prevalence × cohort fix effect.

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