School closure and management practices during coronavirus outbreaks including COVID-19: a rapid narrative systematic review

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Summary

In response to the COVID-19 pandemic, 107 countries had implemented national school closures by 18 March 2020. It is unknown whether school measures are effective in coronavirus outbreaks e.g. due to SARS, or MERS and COVID-19. We undertook a systematic review of 3 electronic databases to identify what is known about the effectiveness of school closure and other school social distancing practices during coronavirus outbreaks.

We included 16 of 611 identified articles. School closures were deployed rapidly across China and Hong Kong for COVID-19. However, there are no data on the relative contribution of school closure to control of transmission. Data from the SARS outbreak in China, Hong Kong and Singapore suggest that school closures did not contribute to control of the epidemic. Modelling studies of SARS produced conflicting results. Recent modelling studies of COVID-19 predict that school closure alone would prevent only 2-4% of deaths, much less than other social distancing interventions.

Policymakers need to be aware of the equivocal evidence when considering school closures for COVID-19, and that combinations of social distancing measures should be considered. Other less disruptive social distancing interventions in schools require further consideration if restrictive social distancing policies are implemented for long periods.

Research in context

Evidence before this study

Five systematic reviews have examined the effects of school social distancing, particularly school closures, on disease transmission during influenza outbreaks. School closures are likely to have the greatest effect if the virus has low transmissibility and attack rates are higher in children than adults.

The effects of school closure are reduced by continued child-child social contacts outside school and potentially increase child-adult contacts due to the need for unofficial and grandparent child-care. The economic harms of school closures are high. Costs have been estimated to be as high as 0.2-1% of UK national gross domestic product (GDP) for school closure for 12-13 weeks.

Forced work absenteeism of healthcare staff due to school closures can significantly reduce the benefits of school closures.

Added value of this study

We provide the first rapid systematic review of the evidence of benefit of school closure and other school social distancing interventions in coronavirus outbreaks i.e. SARS, MERS and COVID-19.

Data from the SARS epidemic do not support a role for school closures in the control of coronavirus infections. Emerging data from the COVID-19 pandemic provide little evidence for the effects of school closures separately to other infection control measures. Modelling studies suggest that the school closures alone contribute much less than other social distancing measures to control of the pandemic, with estimates closing schools may reduce deaths from COVID-19 by 2-4%.

Implications of all the available evidence

There is a lack of policy-relevant data on implementation of school social distancing during coronavirus outbreaks. Whilst all averted deaths are important, one modelling study suggests benefits of school closures alone are small compared with other measures. Data from influenza outbreaks showing benefits of school closures cannot necessarily be applied to COVID-19. Indeed, systematic reviews suggest that school closures have only small effects in infections with a high reproductive number (R) and where children are not the main drivers of infection, such as in COVID-19. Policymakers need to be aware of the equivocal evidence when proposing or implementing national or regional school closures for COVID-19, given the very high costs of lengthy school closures during pandemics. Given predictions that social distancing measures may need to be in place for many months or even years, there is an urgent need to identify how countries can in time safely return students to education and parents to work. Other less disruptive social distancing interventions in schools need further consideration and research.

Background

The World Health Organisation (WHO) declared the COVID-19 outbreak to be a pandemic on 12 March 2020.[1] UNESCO estimated on 18 March that 107 countries had implemented national school closures related to COVID-19, affecting 862 million children and young people, roughly half the global student population. This had rapidly escalated from 29 countries with national closures a week previous.[2] School closures are based upon evidence and assumptions that they reduce social contacts between students and therefore interrupt transmission.[3]
School closures can affect deaths during an outbreak either positively, through reducing transmission and the number of cases, or negatively through reductions in the healthcare workforce available to treat the sick. Studies of UK children and young people report that the mean number of daily social contacts during school holidays are approximately half that of school term days;[4,5] however contacts continue and mixing between children and adults and between children at different schools actually increases during holidays and school closures.[4-7]

The evidence for the effectiveness for school closures and other school social distancing measures comes almost entirely from influenza outbreaks, for which transmission of the virus tends to be driven by children. It is unclear whether school measures are effective in coronavirus outbreaks e.g. due to SARS, or MERS and most specifically, COVID-19, for which transmission dynamics appear to be different.

School closures and influenza outbreaks

Five systematic reviews of the effects of school closure on influenza outbreaks or pandemics suggest that school closure can be a useful control measure, although the effectiveness of mass school closures is often low. School closure strategies may be national, regional, local or reactive closure of individual schools due to student infection rates. A systematic review commissioned by the UK Department of Health in 2014, to inform Influenza Pandemic Preparations, included 100 epidemiological and 45 modelling studies and concluded that: 1) school closures can reduce transmission of pandemic influenza if instituted early in outbreaks; 2) school closure results in greater reductions in peak than in cumulative attack rates; and 3) according to modelling studies school closures are likely to have the greatest effect if the virus has low transmissibility (R<2)and attack rates are higher in children than adults.[8] A second review of modelling studies by the same authors drew similar conclusions.[9]

A 2018 review of 31 studies that addressed whether school closure had a quantifiable effect on influenza transmission reported that school closure reduced the peak of the related outbreak by a mean of 29.7% and delayed the peak by a median of 11 days.[10] They also reported that earlier school closure predicted greater reduction in the outbreak peak, though these latter estimates did not come from formal meta-analyses.[10] A 2015 systematic review of social distancing practices, including school closures, for influenza pandemics reported a wide variation in reduction of transmission (range 1-50%) but noted that there is evidence that up to 70% of students may shift social contacts to other non-school sites during closures, reducing the impact of closures.[11]

A 2020 systematic review of school closures and other social distancing measures during influenza outbreaks also concluded that there was compelling evidence that closures reduced transmission, particularly among school-aged children. The authors noted however that there was substantial evidence that transmission surged again once schools re-opened and that there was little consensus on the appropriate timing of closures, let alone reopening of schools.[12]

One way that school closures are effective during outbreaks may be through forcing parents to work at home and thus reducing work-related contacts. However reviews have also noted the adverse effects of school closure, including economic harms to working parents, healthcare workers and other key workers being forced from critical work to childcare, and to society due to loss of parental productivity, transmission from children to vulnerable grandparents, loss of education, harms to child welfare particularly among the most vulnerable students, and nutritional problems particularly where free school meals are an important source of nutrition.[8,10,11] Social isolation itself brings a range of psychological harms.[13] An unpublished rapid review by Brooks et al examined how unplanned school closures affected children's activities and contacts. This found evidence that such activities and contacts decreased but did not cease, with some evidence that this was particularly so among older children and those whose parents disagreed with closures.[7]

The economic harms of school closures are high. A UK study from 2005 suggested that approximately 16% of the workforce are the main caregivers for dependent children and are at very high risk of absenteeism if schools are closed, a proportion that rises to 30% in the health and social care sectors.[14] In the US, unpublished estimates suggest that 29% of healthcare workers have childcare obligations.[15] A 2010 economic modelling analysis of school closures as mitigating interventions during influenza outbreaks suggested that 4 or 13 week closures reduced the clinical attack rate minimally but markedly increased the economic cost to the nation, in particular through forced absenteeism by working parents.[16] Costs have been estimated to be as high as 0.2-1% of UK national gross domestic product (GDP) per annum for school closure for 12-13 weeks[14] or up to 3% of GDP for an 8 week closure in US studies.[17] Reviews have not summarized economic harms from school closure in detail, but economic modelling from an influenza outbreak in Hong Kong suggested that the most cost-effective models were selective local closures rather than national closures.[18]

Note that regardless of official school closure or other distancing policies, unofficial student and staff absenteeism (whether due to illness or precautionary) can be very high during epidemics. Staff absenteeism can lead to forced local school closures.[19]

Other school management practices

School dismissal, whereby all students except the most vulnerable and/or children of healthcare and other essential workers, are sent home but the school stays open, has been suggested to be a less strict intervention than school closure, although there is no evidence supporting its use separately to full closure.[20]

There are many other potential social distancing actions available for schools that are less drastic than full closure, although these have received little attention.[21] A 2018 systematic review of such strategies noted that potential practices include suspending affected classes or grades, or changing school organisation to reduce student mixing (e.g. by closing playgrounds, cancelling non-essential activities and meetings, keeping students in constant class groups/classrooms, increasing spacing between students in classes, reducing the school week and staggering school start and lunch/break times across years or classes).[21] The review concluded that the literature was very limited but that a small number of modelling studies supported use of alternative strategies during influenza outbreaks.[22,23] There were no UK studies included in this review.[21] In the 2009 H1N1 influenza pandemic, Taiwan instituted class suspensions rather than school closures, facilitated by Taiwanese students remaining in a home-room with a core teacher with other teachers routinely moving between classes. Studies suggest that this was an effective social distancing measure in this outbreak whilst reducing social disruption.[24]

COVID-19 and school closures

As noted above, by March 2020 many countries have instituted large scale or national closure of schools aimed at reducing transmission of COVID-19. These actions appear largely based upon assumptions that the benefits apparent in influenza outbreaks are also likely for COVID-19.

There are a number of theoretical reasons why school closures may be less effective in COVID-19 than in influenza outbreaks. Children contribute more to influenza transmission than do adults,[25] with low levels of immunity and high levels of transmission due to symptomatic disease. However, in the COVID-19 epidemic thus far, children may form a much lower proportion of cases than expected from their population, although evidence for this is mixed and the most recent data suggest that children may be as likely to be infected as adults but largely remain asymptomatic or have mild disease.[26] It remains unclear whether the low proportion of confirmed COVID-19 cases among children in China relate to: reduced risk of infection; having subclinical or milder infections; or specific population factors in China (e.g. one child policy). Evidence of COVID-19 transmission through child-child contact or through schools is not yet available, although family transmission is central.

In some previous coronavirus outbreaks, evidence suggested that transmission in schools was very low or absent.[27] As modelling studies of school closures for influenza outbreaks rely on assumptions about the proportion of cases transmitted in schools being relatively high,[28] these models cannot be assumed to be informative regarding effectiveness for COVID-19. Emerging epidemiological data suggest that there has been little evidence of transmission through schools in China, although this may reflect closure of schools during most of the outbreak.[29] At the time of writing, Taiwan has been recognised to have effectively minimised spread of COVID-19[30] but with national policies having avoided widespread planned school closures and instead mandating initially local class closures then local temporary school closures based upon low thresholds for infected cases within individual schools.[30]

In view of the lack of information and pressure on countries to consider school closures to deal with the COVID-19 pandemic, we performed a rapid systematic review of the literature to answer the question: what is known about the use of and effectiveness and cost-effectiveness of school closure and other school social distancing practices on infection during coronavirus outbreaks?

Methods

Selection criteria and search strategy and selection criteria

We sought to include quantitative studies using a diversity of designs to model or empirically evaluate the effects of school closure and other school social distancing practices on infection during coronavirus outbreaks. Our search was designed to be inclusive of any studies providing data on schools or nurseries.

We undertook searches of electronic databases on 9 March and again on 19 March, as follows:

1. PubMed
We searched PubMed using the following search terms:
Syntax: ((SARS[tw] OR "severe acute respiratory syndrome"[mh] OR "severe acute respiratory syndrome" OR "Middle East Respiratory Syndrome Coronavirus"[mh] OR "middle east respiratory syndrome*"[tw] OR "MERS-CoV"[tw] OR Mers[tw] OR "Middle Eastern Respiratory Syndrome*"[tw] OR "MERSCoV*"[tw] OR coronavirus[mh] OR Coronavirus Infections[mh] OR coronavirus*[tw] OR

"COVID-19"[tw] or "2019-nCoV"[tw] or "SARS-CoV-2"[tw]) AND (Schools[mh:noexp] OR schools, nursery[mh] OR "Child Day Care Centers"[mh] OR "Nurseries, Infant"[mh] OR school[tiab] OR schools[tiab] OR preschools[tiab] OR preschool[tiab] OR "pre school"[tiab] OR "pre schools"[tiab] OR nursery[tiab] OR nurseries[tiab] OR kindergarten[tiab] OR kindergarten[tiab] OR (("day care" OR daycare) AND (child* OR infant*))))

The search identified 119 articles. All articles were triple screened (SR, HC, JP) on title and abstract. We excluded opinion pieces, systematic reviews, studies addressing other viruses, university-specific settings, epidemiological studies not examining intervention effects (e.g. of prevalence of infection in schools) and studies in Chinese with no translation. This resulted in 22 potentially eligible studies for which full texts were obtained. Full text review was conducted and 8 articles were included in the review.

2. WHO Global Research Database on COVID-19.
As a search using the term 'school' only retrieved 1 article (excluded as it did not contain research), we undertook a 2-stage search. We initially used the search terms *child, children, childhood, infant, baby, babies, pediatric, paediatric* and identified 17 papers, of which 7 were excluded as lacking English translations. Secondly, we retrieved the full text of the remaining 10 studies to identify any relevant to the search question. No articles were included.

3. preprint server medRxiv.
We searched medRxiv for all papers related to the search terms 'SARS or MERS or coronavirus or COVID-19'. It was not judged useful to include search terms relating to schools as the search facilities were not sophisticated. The search yielded 480 articles, which were double screened by SR, HC, JP, using exclusion criteria consistent with the PubMed searches. 36 articles were considered potentially relevant on title and abstract review. After full text review, 6 were included.
4. Hand and citation searching
For each retrieved full text article, we hand searched included references and examined the citation chain for additional studies. 1 additional article was identified.

5. Additional papers: One additional modelling study published as a non-peer reviewed report was identified and included.[31]
Full text articles were reviewed in each case by RV.

Quality: We made no attempt to rate the quality of included studies in this rapid review. We considered findings from preprint articles separately to published peer-reviewed articles.

Findings

Sixteen studies (9 published peer-reviewed papers, 6 preprint papers and 1 report) were included in the review (see Figure 1).

Organism: All published papers concerned the 2003 SARS outbreak. One preprint concerned the impact of school closures on transmission of other (endemic) coronaviruses (229E, NL63, OC43, HKU1) and five preprints and one report concerned the COVID-19 pandemic.

Study type: Six papers described and/or evaluated school actions as part of control measures undertaken in response to the SARS outbreak in Taiwan,[24] Singapore[32-34] and Beijing, China.[35,36] Two papers were modelling studies that estimated SARS transmission in schools[37] or the impact of school closure[38] on transmission in SARS outbreaks. One paper reported qualitative research with healthcare workers post SARS relating to the impact of school closures.[39] Five preprint papers reported on school closures during the COVID-19 outbreak in China[40-42] and Hong Kong.[12,43] One

preprint paper described the impact of school closure on winter transmission of other human coronaviruses.[44] One report modelled the impact of school closures in the UK on transmission of COVID-19.[31]

Effectiveness of school social distancing measures

COVID-19

Preprint studies report that school closures were initiated nationally across China in late January 2020 (manifesting as delaying the restarting of schools after Chinese New Year holidays) as part of a broader series of control measures during the COVID-19 epidemic. No data are available on the effectiveness of school closure as: 1) there was little variation in timing of closures (closures were reportedly applied in all Chinese cities uniformly and without delay); and 2) school closures were part of a broad range of quarantine and social distancing measures. Both studies concluded that the overall package of quarantine and social distancing was effective in reducing the epidemic in China,[40,41] although the relative contribution of school closures was not assessed.

Preprint studies of actions in Hong Kong related to COVID-19 noted that a 4-week school closure was initiated across Hong Kong on 1 February, approximately 1 week after the first cases were identified in Hong Kong. School closures were implemented at the same time as a number of other stringent social distancing measures, with school closure extended initially to March then April 2020.[12,43] Collectively these measures were considered to have reduced the *R* below 1, controlling the spread of the outbreak.[12] As in China, no data were available from either paper on the impact of school closures separate to other measures. Cowling et al. 2020 noted that the social distancing measures implemented during the COVID-19 outbreak reduced community transmission by 44%, which was much greater than the estimated 10-15% reduction in influenza transmission conferred by school closures implemented alone during the 2009 pandemic in Hong Kong.[12,43]

SARS

Schools were closed during the SARS epidemic in Beijing on 24 April 2003, approximately 6 weeks after the beginning of the outbreak, remaining so in many cases for over 2 months. The authors concluded that school closures made very little difference to the prevention of SARS in Beijing, given the very low attack rate in schools before closure and the low prevalence of disease in children during the SARS.[35] A second study estimated the effective reproductive number (*R*) for each day of the Beijing SARS outbreak, noting that school closures occurred after the *R* had dropped below 1 and that school closures in this case added little to control of the outbreak.[36] Class cancellation strategies, in which upper high-school and college students remained on college campuses but did not attend classes, were also widely used during the SARS outbreak in China.[45] There was no recorded transmission of SARS in schools during the outbreak in China.[46]

A review of the 2003 SARS outbreak in Singapore noted that twice-daily mandatory temperature screening of all children 6-16 years in schools was part of the containment measures instituted. Pupils were excluded from school if their temperature was >37.8°C for students aged ≤12 years old or >37.5°C for students aged >12 years old.[32] While there were school children diagnosed with SARS in Singapore, none were identified through temperature screening.[34] All educational facilities in Singapore were closed for 3 weeks from 27 March 2003 (the SARS outbreak ran from late February to May 2003) together with suspension of other activities to prevent the congregation of large groups of children.[33]

A review of responses in Taiwan to the SARS and 2009 H1N1 influenza pandemics noted that schools were designated as alternative health care sites in case the health system was overwhelmed during the SARS outbreak, but that there were no school social distancing measures (including closures)

introduced during the SARS outbreak.[24] This is in contrast to the use of class suspensions during the H1N1 pandemic in Taiwan.[24]

Schools were also closed in Hong Kong during the SARS epidemic; however, the extent to which this was national or local is unclear. There was no evidence of spread of infection in schools, with spread among children almost entirely through family settings and apartments.[27]

Endemic coronaviruses
An unpublished study by Jackson et al. used routinte viral surveillance to examined the effects on transmission of endemic human coronaviruses (229E, NL63, OC43, HKU1) and other viruses of a 5-day closure of nearly all schools in the greater Seattle metropolitan area in February 2019 due to extreme weather on transmission of endemic human coronaviruses (229E, NL63, OC43, HKU1) and other viruses using routine viral surveillance. This estimated that the school closure resulted in a 5.6% (95% CI: 4.1, 6.9) reduction in coronavirus infections, similar to influenza H1N1 (7.6%) but higher than influenza H3N2 (3.1%) all of which were prevalent at the time.[44]

Modelling studies

COVID-19

An unpublished modelling study examined the impact of school closure together with other social distancing measures in Wuhan. This used transmission data representative of COVID-19 but it was unclear whether epidemiological data from the outbreak were used further in the modelling. This study concluded that the package of social distancing measures was effective in reducing the final size and peak incidence of the outbreak while also delaying the peak.[42] However, the study did not examine the impact of school closures relative to other measures. It modelled different timings of relaxation of social distancing measures, and concluded that earlier relaxation (after 2 months of restrictions) risked a second peak whereas 3 months of restrictions did not result in a second peak.[42]

Only one study has examined the impact of school closures separately to other social distancing measures. In a non-peer reviewed report from an established group, Ferguson et al. 2020 modelled the estimated impacts of a range of different social distancing measures and combinations of measures. They used UK population and schools data together with data on transmission dynamics reported from the COVID-19 outbreak in Wuhan.[31] They assumed using data from previous influenza outbreaks that per-capita contacts within schools were double those in households, workplaces or the community, and that, overall, approximately one-third of transmission occurred in schools. They modelled a scenario in which all schools were closed together with 25% of universities and where the impact on non-school social contacts was an increase of 50% in household contact rates for families with children and a 25% increase in community contacts during the closure. They concluded that school closure as an isolated measure was predicted to reduce total deaths by around 2-4% during a COVID-19 outbreak in the UK, whereas single measures such as case isolation would be more effective, and a combination of measures would be most effective. Fergusson et al concluded that school closure is predicted to be insufficient to mitigate (never mind suppress) an epidemic in isolation. This is in contrast to seasonal influenza epidemics where children are the key drivers of transmission.[31]

SARS
An early modelling study of a SARS-like illness in school children concluded that a school closure policy would reduce the effective *R* by 12-41% depending on the proportion of between-household mixing that occurred during school hours. The study noted that modelling was based upon ‘plausible

assumptions' regarding SARS behaviour, noting that obtaining good quality estimates of epidemiological parameters for SARS was difficult as the outbreak was contained rapidly.[38]

A modelling study of the transmission of SARS in hospitals and in elementary school classrooms in Taiwan using data from the 2003 SARS outbreak concluded that a single case of SARS would infect 2.6 secondary cases on average in a population from transmission in hospital, whereas less than 1 secondary infection was generated per case in a school classroom.[37]

Broader societal issues

Conflict between the work and family requirements of healthcare professionals during the SARS epidemic was explored in qualitative research with 100 Canadian emergency and critical care nurses, many of whom had been involved with the SARS outbreak. The study found that heathcare workers experience substantial personal dilemmas in balancing work and family commitments, particularly relating to child-care needs if schools or child-care are closed. The study concluded that there was a need for provision of adequate resources to protect the families of healthcare workers during outbreaks to maintain maximal staffing.[39]

Discussion

This rapid review provides the first summary of data on school closures and other social distancing practices during coronavirus outbreaks. We were able to include only 9 published studies and 7 as yet non-peer reviewed studies. We decided to include un-reviewed studies as data would not otherwise be available on COVID-19, although findings were interpreted with caution. With the exception of one modelling study, none of the included studies were designed to specifically examine the effectiveness of school distancing measures. Thus data provided on the impact of school measures were of relatively low quality.

We identified a remarkable lack of policy-relevant data on implementation of school social distancing during coronavirus outbreaks. This is perhaps not surprising for the rapidly emerging COVID-19 pandemic, but previous coronavirus outbreaks such as SARS and MERS provide limited information about the effectiveness of school closures and no data on cost-effectiveness. We identified no data on other less disruptive school social distancing practices during coronavirus outbreaks.

Data from the SARS outbreak in China, Hong Kong and Singapore suggest that school transmission played no significant role in the outbreak, and that school closures and other activities such as school temperature monitoring did not contribute to control of infection transmission. It is possible that these reflect an effect of school closures in rapidly stopping transmission. However, this is unlikely as schools remained open for significant periods during the early part of the outbreak in each country. Modelling studies from the SARS outbreak produced differing results. Whilst Becker et al. 2005 estimated that school closure resulted in potentially important reductions in transmission, Liao et al. 2005 estimated that transmission in school classrooms was low.

School closures were rapidly deployed across mainland China and Hong Kong in early 2020 as part of a wider set of control measures for COVID-19, with the result that no data were available on the comparative effectiveness of school closure interventions in isolation. Authors of unpublished studies concluded that school closures likely contributed to the control of COVID-19 in China as part of a package of very broad quarantine measures. However, they provide no data to back up this assertion and indeed it may be very difficult to disentangle the relative contribution of school closures.

Modelling studies from the COVID-19 pandemic support the use of national school closure as part of a package of social distances measures. Yet the only study to examine school closure as a separate intervention warned that the impact was relatively marginal, given the reasonable assumptions that household and community contacts would rise as a consequence.

Conclusions and policy implications

There are few data available from the literature on coronavirus outbreaks to guide countries on the use of school closures or other school social distancing practices during COVID-19. Available evidence is consistent with a broad range of impacts of school closures, from little impact on reducing transmission through to more substantial effects. Yet the economic costs and potential harms of school closure are undoubtedly very high.

As evidence from corona virus outbreak control is limited, we must turn to evidence for the benefits of school closures from influenza epidemics and pandemics. School closures have been widespread in some countries during influenza pandemics, and many studies report important impacts on reducing transmission and the size of the pandemic. Yet there is considerable heterogeneity in the impact of school closures on transmission depending on characteristics of influenza serotype transmission. Systematic reviews of influenza outbreaks suggests that school closures are likely to have the greatest effect if the virus has low transmissibility ($R < 2$), particularly if attack rates and transmission are higher in children than adults.[8] While our information on SARS-CoV-2 remains incomplete, this appears not to be the case with COVID-19. Reported *R* for COVID-19 are high (2.5 or higher).[47] Whilst children appear to contract infection at the same rate as adults, they largely have mild or asymptomatic disease and appear therefore to be less likely to spread the virus through coughing or sneezing, although a precise understanding is lacking. It is notable that analyses using UK clinical data from the 1957 (Asian) influenza pandemic suggest that closure of schools would reduce the epidemic size by less than 10% when the *R* was similar to COVID-19 (i.e. 2.5-3.5).[48] Reviews also note that the benefits of school closure may be less than assumed or modelled as social contacts between children and children and adults continue as part of informal child-care and non-school gatherings of children and young people.[11] This is a particular concern for COVID-19, with its higher mortality amongst the elderly, as around 40% of the UK's grandparents provide regular childcare for their grandchildren.[49]

The WHO Director General noted on 12 March 2020 that "All countries must strike a fine balance between protecting health, preventing economic and social disruption, and respecting human rights."[1] Currently the evidence to support national closure of schools to combat COVID-19 is very weak and data from influenza outbreaks suggest that school closures may have relatively small effects on a virus with COVID-19's high transmissibility and apparent low impact upon school children. Yet these same data show that school closures can have profound economic and social consequences.

More research is urgently needed on the effectiveness of school closures and other school social distancing practices in COVID-19. We also need more detailed knowledge about how COVID-19 affects children, as the role of school measures in reducing COVID-19 transmission depends on the susceptibility of children to infection and their infectiousness once infected.[12] However observational studies may be relatively uninformative if closures are national and implemented at the same time as other mitigation measures. Better learning may come from countries that have instituted later or subnational closures. Modelling studies, particularly those parameterised for COVID-19 in children, and that can consider interaction with other contextual factors (e.g. timing, parents working from home, additional social mixing as a consequence of school closures) or

different strategies (national vs staged roll out) are likely to be more informative and are urgently needed.

These findings pose a dilemma for policy-makers seeking measures to protect populations. School closure presents an apparently common-sense method of dramatically reducing spread of disease and the evidence from previous influenza outbreaks appears compelling. Yet policymakers need to be aware of the equivocal evidence when proposing or implementing national or regional school closures for COVID-19, given the very high costs of lengthy school closures during pandemics. Decisions about closures and their timing and length involve a series of trade-offs between conflicting factors, and a substantial loss of healthcare staff to child-care duties during closures may substantially reduce any benefit to health systems and populations brought by closures of schools.[50] Nonetheless, in a context of high rates of staff absence through disease, school systems will be under strain and schools remaining open only for the children of healthcare and other essential workers may be a better strategy than a haphazard process of schools closing and therefore providing no childcare for any essential workers.

The scale and speed of school closures are unprecedented globally. Yet it is unclear how long countries can maintain tight suppression measures before behavioural fatigue in the population occurs.[31] Given predictions that social distancing measures may need to be in place for many months or even years,[31] there is an urgent need to identify how countries can safely return students to education and parents to work. Education is one of the strongest predictors of the health and the wealth of a country's future workers, and the impacts of long-term school closure on educational outcomes, future earnings and health of young people and on future national productivity have not been quantified.

Once numbers of cases begin to fall, the measures used to achieve suppression might evolve over time. Schools have begun to reopen in parts of China,[2] and it will be essential for studies to monitor the impact of the reopening of schools on numbers of cases. It will also be important to examine countries which have not closed schools. Taiwan reopened schools in late February 2020, relatively early in the outbreak and has not initiated further national closures but has been recognised to have effectively minimised spread of COVID-19. Policymakers and researchers should also look to other school social distancing interventions that are much less disruptive than full school closure, and may significantly contribute to maintaining control of the pandemic. Whilst strong evidence is lacking for the effectiveness of these practices, they may be implementable with much less disruption, financial costs or harms. Modelling and observational studies are urgently needed to guide policy on the opening of schools once the pandemic is under control.

Contributions

RV conceptualised the paper, undertook full text reviews and data extraction and wrote the paper. Searches and screening were undertaken by SR, HC and JP, advised by CS. JW and OW contributed to screening. RB, CB and OM helped revise the paper and consider policy implications. All authors contributed to revision of the final paper.

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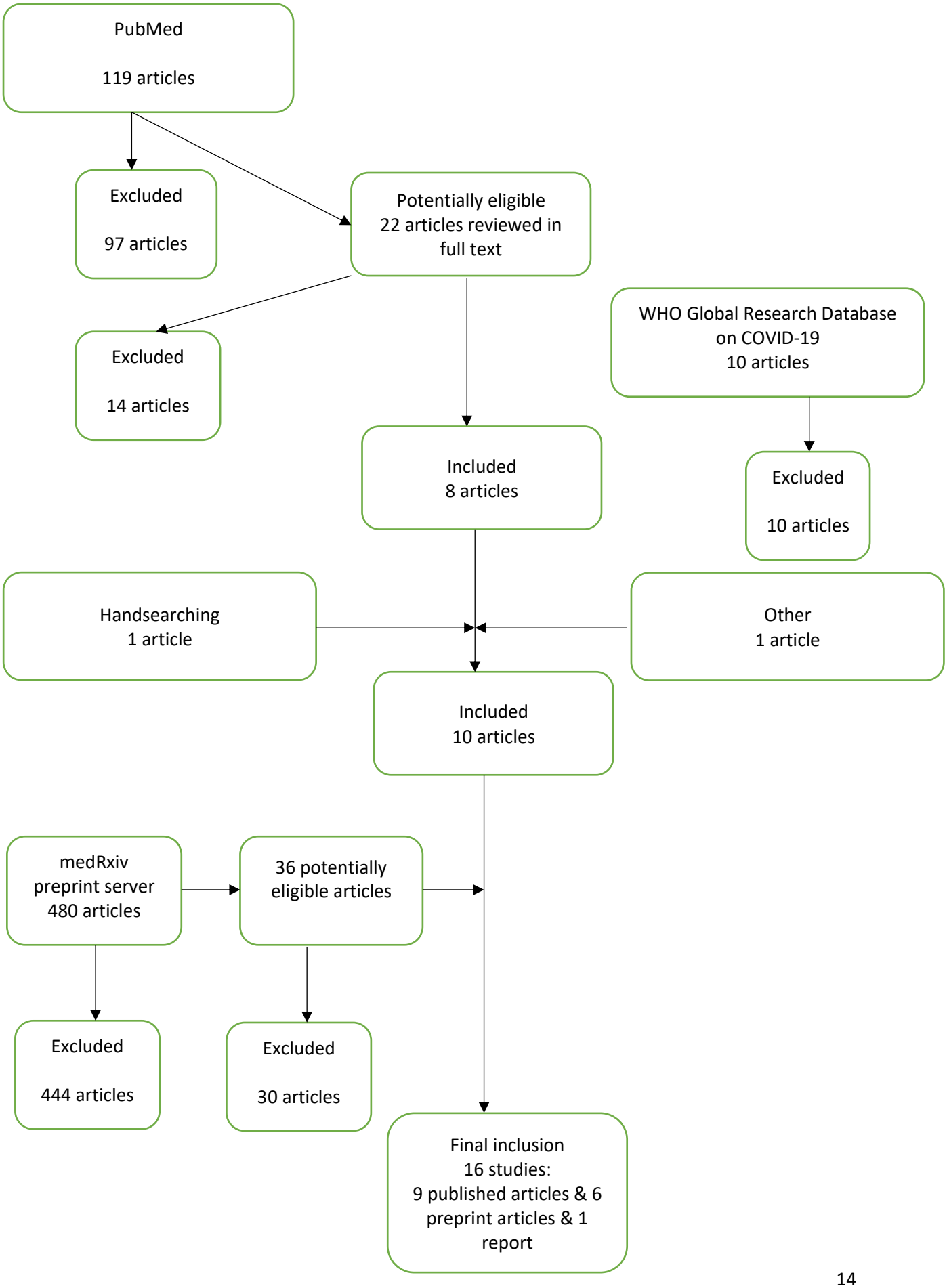
Conflicts of interest.
All authors declare they have no conflicts of interest.

Figure 1. Flow chart for search



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