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BMJ Paediatrics Open

The role of children in the transmission of the COVID-19 pandemic: a scoping review

Journal:	<i>BMJ Paediatrics Open</i>
Manuscript ID	bmjpo-2020-000722
Article Type:	Review
Date Submitted by the Author:	01-May-2020
Complete List of Authors:	Rajmil, Luis
Keywords:	Epidemiology, Virology

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3 Title:

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5 **The role of children in the transmission of the COVID-19 pandemic: a scoping review**
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26 **Abstract**

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28 As a response to the COVID-19 pandemic most countries adopted measures of social distance,
29 with childhood population being one of the main focus of attention in these measures. A brief
30 scoping review was carried out by searching PubMed to know if children are more contagious
31 than adults, and the proportion of asymptomatics. Nine out of 761 identified articles were
32 finally included. Studies included cases from China (N= 9 to 2143), China and Taiwan (n=536),
33 Korea (n=1), and Vietnam (N=1). Although no complete data were available, between 15% and
34 55-60% were asymptomatic, and 75-100% of cases were from family transmission. This review
35 suggest that children are not transmitter to a greater extent than adults, highlight the need for
36 improve the validity of epidemiologic surveillance to solve current uncertainties, and to take
37 into account social determinants and child health inequalities during and after the current
38 pandemic.
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43 **Keywords:** children, COVID-19; transmission
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45 Number of words in the text: 1297

46 Number of words n the abstract: 144

47 References: 27

48 Tables: 1
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Intro

The COVID-19 pandemic started in late 2019 in China has represented a substantial change in the health of the population worldwide, especially for families and children.^{1,2} This pandemic and the lack of effective treatment so far until now, highlight the need to take measures to prevent the spread of the infection. Measures adopted based on the best scientific available evidence were usually according to previous knowledge mainly based on other pandemics. Nevertheless, it should also be taken into account the data available from the current pandemic given there are several unknown questions. In the current situation measures taken to prevent the spread of the pandemic are generally based on the precautionary principle, and these measures should balance the potential side effects with the infection itself.

In the case of children, data available seems to indicate that they are equally susceptible to presenting infectious symptoms, although less severe compared to the adult population and the elderly.³ At the moment there are no certainties about the possible causes of this situation. There is also insufficient information on the child population as a vector of transmission of the infection. Despite this, in the majority of countries one of the first measures adopted has been the closure of schools and even in some countries, such as Spain, the house confinement of all minors was specifically decided for at least 45 days.⁴ These strict measures taken with children are probably associated with experiences in previous epidemics like influenza where children had a central role in the spread of this virus in the community during epidemics.⁵ Up to date there are many uncertainties regarding these issues in the current COVID-19 pandemic.

Given this situation and the uncertainty on the transmission mechanisms, prediction of severity, the spread of infection in asymptomatic patients, or immunity after infection, a systematic scoping review of the published data was carried out to try to move forward in answering the following questions: are children more contagious than adults? Are they proportionally more asymptomatic?

Methods

A scoping literature review was carried out by search in PubMed using the following terms: "coronavirus or COVID-19 or SARS-CoV-2" and "neonates or pediatric or infant or children or adolescence" and "transmission" to find reports of pediatric COVID-19. The time period was restricted to the last four months, from December the 1st 2019 to 04/24/2020. Available full texts and the reference lists of the relevant studies were reviewed.

Inclusion/exclusion criteria

All studies published in English, Italian, French or Spanish related to the transmission of COVID-19 in children were included, as well as those who compare the percentage of asymptomatic patients according to age and also the source of contagion when this was possible.

Studies that did not present data on childhood population were excluded, as well as those that focused the data exclusively on the level of severity and / or hospitalizations and / or pediatric intensive care units (PICU), or the treatment. All kind of studies (case series, cohort studies, comments, Editorials, etc.) were included although the emphasis was stated on those descriptive studies of cases. It is not ruled out that there may be some duplication in the cases included. A description of the results obtained was carried out. It was not attempted to rate the quality of included studies in this Review. Preprint articles and pre peer-reviewed articles were also included if they were of specific interest.

Results

Of the 761 initial titles, 50 articles were selected for reading the full text. Of these, 9 articles were finally included.

Table 1 shows the results of included studies. Studies reported data from China, Taiwan, Korea, and Vietnam. Cao et al.⁶ found that 2.1% of 44672 confirmed cases were children or adolescents, mainly from intrafamilial clusters. One of the larger series also based on the report of 2143 pediatric cases from China⁷ shows that 44% were asymptomatics and the main source of transmission seems to be the family (no data available). It should be taken into account that in the latter case series only 34% of cases of COVID-19 were confirmed and 66% were suspected cases. The first case reported from Korea⁸ (10y old) and Vietnam⁹ (3 months old) were also associated to family transmission. A study from the hospital of Wuhan addressed to pediatric patients¹⁰ found that 171 out of 1391 screened cases were positive, 15% were asymptomatic cases and 90% of confirmed cases were from family transmission. A systematic review of 9 case series included 93 cases and reported that 26% were asymptomatics, and 75% were from family transmission.¹¹ Another series of 9 cases from 14 families,¹² 36 cases (out of 616 population),¹³ and 14 children (and 53 adults)¹⁴ found that 6, 18, and 8 children were asymptomatics, respectively. All cases in children were from family transmission.

Discussion

The results of the present review suggest that children would be asymptomatics as frequently as adults, and that a high percentage of reported cases came from family transmission. Although there are still many uncertainties, it does not appear that children are transmitters to a greater extent than adults. As previously mentioned, the drastic measures taken in the child population in several countries have probably been based on previous epidemics such as influenza,¹⁵ without enough evidence of the current situation. Moreover, there are some theoretical reasons why school closures might be less effective in COVID-19 than in influenza outbreaks. A systematic review found that modelling studies of COVID-19 predict that school closures alone would prevent only 2–4% of deaths, much less than other social distancing interventions.¹⁶

No studies were found on the subject of the present review neither from Spain, France, Italy nor the United States, countries strongly affected by the pandemic. Studies from these countries to date have been addressed mainly to analyse severity of identified pediatric cases, the need of Pediatric Intensive Care Unit (PICU), or immune responses in children.¹⁷⁻²⁰ Nevertheless, the results of this review are likely to be generalisable at least in those countries where initial measures included closing schools.

Other secondary questions that come out from this review are the differences in the incubation period and the evidence that children (and probably also adults) can excrete the virus in feces.⁶ According to some authors asymptomatic individuals can actively shed the virus. Further, the incubation period in children following exposure to the virus can range upward of 24 days.²¹

The importance of children in transmitting the virus still remains uncertain. Children more often have gastrointestinal symptoms compared with adults. The majority of children infected

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3 by novel CoVID-19s have a documented household contact, often showing symptoms before
4 them.²²
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6 If children are important in viral transmission and amplification, social and public health
7 policies (eg, avoiding interaction with elderly people) could be established to slow transmission
8 and protect vulnerable populations. Nevertheless, the application of the precautionary
9 principle should be evidence-based as much as possible and try to avoid creating adverse
10 effects with potential medium and long-term negative impact on the childhood population. A
11 study analysing viral load by age in a sample of 3712 patients from Berlin found no differences
12 by age on viral loads; even in the very young patients do not differ significantly from those of
13 adults.²³
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16 Among the limitations of the present review should be mentioned the current lack of reliable,
17 valid and comparable data on epidemiologic surveillance,²⁴ on the diagnostic tests, and the
18 scarce knowledge on the mechanism of transmission and prognostic.^{25, 26} High quality
19 epidemiological studies are necessary to solve these questions with certain plausibility. On the
20 other hand, up to date there are scarce data on the socioeconomic factors and its influence on
21 the current pandemic. Social determinants of child health should be addressed to enhance the
22 positive effects and avoid the adverse effects of this pandemic on children's rights and social
23 inequalities in children's health.²⁷
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Table 1. Characteristics of included studies and main results

First author / Journal	Type of study	Publication date	Country	N total population	Number of pediatric cases	Asymptomatics	Source of transmission / Observations
Cao et al. ⁶ J Formosan Med Assoc	Review of reported cases	02/26	China / Taiwan	44672 laboratory confirmed cases	Number of reported cases comparing with adult population was 0.9% for <10y, and 1.2% for 10-20y	Most showed mild symptoms. No data on asymptomatic cases	Mainly intra-familial cluster circles. Children could become the main spreader when their infection is mild /Stool could be a source of transmission
Dong et al. ⁷ Pediatrics	Epidemiology of pediatrics cases	03/17	China/ Cases recruited from the China Center for Disease Control and prevention		2143 pediatric cases reported; 34% onfirmed; 66% suspected	44% asymptomatics	Not confirmed but family transmission seems to be the main source of cases
Ji Young Park et al. ⁸ J Korean Med Sci	A case study. Brief report	03/16	Korea	-	A 10y old girl. 1rst case detected in Korea	Mild symptoms	Close contact of her uncle and mother who were confirmed
Hai T Le et al. ⁹ Lancet Child Adolesc Health	A case -study	03/23	Vietnam		3 months old girl. 1rst case of infant detected in Vietnam	Nasopharyngeal swabs positive	Contact with her grandmother who was confirmed
Lu X et al. ¹⁰	Correspondence. Serie of cases	03/18	China	Children treated	171/1391 tested were (+).	15% asymptomatic. Three patients	90% confirmed family cluster

New England J Med				at the Wuhan Children's Hospital		required PICU (all with previous chronic conditions)	
Chang et al. ¹¹ J Formosan Med Assoc	Systematic review of 9 case series	02/26	China		93 cases	26% asymptomatics	75% family contact
Su L, et al. ¹² Emerg Microbe Infections	Serie of cases	03/12	China	-	9 cases from 14 families, ages 11 months to 9y	6 cases asymptomatics. The rest of children with mild symptoms and recovered after 2-3 weeks	Family transmission. Five discharged children were admitted again because their stool showed positive result in SARS-CoV-2 PCR.
Qiu et al ¹³ Lancet Infec Dis	Serie of cases	03/25	China	N total= 616	36 cases (6%) in children.	Half of them asymptomatics	Family contact
Du W et al. ¹⁴ Infection	Serie of cases (families)	03/23	China	53 adults	14 children	8 out of 14 children asymptomatic	All cases family clusters

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Journal:	<i>BMJ Paediatrics Open</i>
Manuscript ID	bmjpo-2020-000722.R1
Article Type:	Review
Date Submitted by the Author:	02-Jun-2020
Complete List of Authors:	Rajmil, Luis
Keywords:	Epidemiology, Virology

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26 **Abstract**

27 As a response to the COVID-19 pandemic most countries adopted measures of social distance,
28 with childhood population being one of the main focus of attention in these measures. A rapid
29 scoping review was carried out by searching PubMed to know if children are more contagious
30 than adults, and the proportion of asymptomatics. Fourteen out of 1099 identified articles
31 were finally included. Studies included cases from China (N= 9 to 2143), China and Taiwan
32 (n=536), Korea (n=1), Vietnam (N=1), Australia (N=9), Geneva (N=40), the Netherlands
33 (N=116); Ireland (N=3); and Spain (population based study of IgG, N=8243). Although no
34 complete data were available, between 15% and 55-60% were asymptomatic, and 75-100% of
35 cases were from family transmission. Studies analysing school transmission showed children as
36 not a driver of transmission. Prevalence of COVID-19 IgG antibody in children <15y was lower
37 than the general population in the Spanish study. This review suggest that children are not
38 transmitter to a greater extent than adults, highlight the need for improve the validity of
39 epidemiologic surveillance to solve current uncertainties, and to take into account social
40 determinants and child health inequalities during and after the current pandemic.
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46 **Keywords:** children, COVID-19; transmission

47 Number of words in the text: 1623

48 Number of words n the abstract: 190

49 References: 32

50 Tables: 1

51 Figures: 1
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What is known about the subject

- The COVID-19 pandemic has changed the lives of families and children almost everywhere in the world
- Children are susceptible to present infectious symptoms although less severe compared to the elderly, and the general population
- Given the lack of effective treatment, measures taken by Governments in several countries in order implement social distances included school closure, and even in some cases children were closed at home
- These measures, mainly following the precautionary principle, were based on the experiences of previous epidemics (i.e. influenza); nevertheless, many uncertainties exist regarding the role of children in the transmission of the COVID-19

What this study adds

- This review suggest that children are not transmitter to a greater extent than adults
- Many of the reported cases in children were from family transmission, and the percentage of asymptomatic children was variable (15%-60%)
- This review highlight the urgent need for improve the validity of epidemiologic surveillance to solve current uncertainties
- Measures taken should balance the potential benefits and avoid other potential adverse effects such as increasing social inequalities in children and families

Intro

The COVID-19 pandemic started in late 2019 in China has represented a substantial change in the health of the population worldwide, especially for families and children.^{1,2} This pandemic and the lack of effective treatment so far until now, highlight the need to take measures to prevent the spread of the infection. Measures adopted at the beginning of the pandemic in almost all countries were based on the available evidence of previous epidemics like influenza, where children were major transmitters of the disease, even more than adults.³ Nevertheless, it should also be taken into account the data available from the current pandemic given there are several unknown questions. In the current situation measures taken to prevent the spread of the pandemic are generally based on the precautionary principle, and these measures should balance the potential side effects with the infection itself.

In the case of children, data available seems to indicate that they are equally susceptible to presenting infectious symptoms, although less severe compared to the adult population and the elderly.⁴ At the moment there are no certainties about the possible causes of this situation. There is also insufficient information on the child population as a source of transmission of the infection. Despite this, in the majority of countries one of the first measures adopted has been the closure of schools and even in some countries, such as Spain, the house confinement of all minors was specifically decided for at least 45 days.⁵ These strict measures taken with children present some controversies given that up to date there are many uncertainties regarding these issues in the current COVID-19 pandemic.

Given this situation and the uncertainty on the transmission mechanisms, prediction of severity, the spread of infection in asymptomatic patients, or immunity after infection, a systematic scoping review of the published data was carried out to try to move forward in answering the following questions: are children more contagious than adults? Are they proportionally more asymptomatic?

Methods

A rapid scoping literature review was carried out by search in PubMed using the following terms: "coronavirus or COVID-19 or SARS-CoV-2" and "neonates or pediatric or infant or children or adolescence" and "transmission" to find reports of pediatric COVID-19. Google Scholar, MedRxiv/bioRxiv and secondary hand search have also been done. The time period was restricted to the last five months, from December the 1st 2019 and updated until 05/28/2020. Available full texts and the reference lists of the relevant studies were reviewed.

Inclusion/exclusion criteria

All studies published in English, Italian, French or Spanish related to the transmission of COVID-19 in children were included, as well as those who compare the percentage of asymptomatic patients according to age and also the source of contagion when this was possible.

Studies that did not present data on childhood population were excluded, as well as those that focused the data exclusively on the level of severity and / or hospitalizations and / or pediatric intensive care units (PICU), or the treatment. All kind of studies (case series, cohort studies, comments, Editorials, etc.) were included although the emphasis was stated on those descriptive studies of cases. It is not ruled out that there may be some duplication in the cases included. A description of the results obtained was carried out. It was not attempted to rate the quality of included studies in this Review.

Results

Of the 1099 initial titles, 73 articles were selected for reading the full text. Of these, 14 articles were finally included (Figure 1).

Table 1 shows the results of included studies. Studies reported data from China, Taiwan, Korea, Vietnam, New South Wales (Australia), Geneva (Switzerland); the Netherlands; Ireland, and Spain. Cao et al.⁶ found that 2.1% of 44672 confirmed cases were children or adolescents, mainly from intrafamilial clusters. One of the larger series also based on the report of 2143 pediatric cases from China⁷ shows that 44% were asymptomatics and the main source of transmission seems to be the family (no data available). It should be taken into account that in the latter case series only 34% of cases of COVID-19 were confirmed and 66% were suspected cases. The first case reported from Korea⁸ (10y old) and Vietnam⁹ (3 months old) were also associated to family transmission. A study from the hospital of Wuhan addressed to pediatric patients¹⁰ found that 171 out of 1391 screened cases were positive, 15% were asymptomatic cases and 90% of confirmed cases were from family transmission. A systematic review of 9 case series included 93 cases and reported that 26% were asymptomatics, and 75% were from family transmission.¹¹ Another series of 9 cases from 14 families,¹² 36 cases (out of 616 population),¹³ and 14 children (and 53 adults)¹⁴ found that 6, 18, and 8 children were asymptomatics, respectively. All cases in children were from family transmission. In New South Wales schools 9 cases of students of Primary schools and High schools were reported, and one case was detected after 863 contacts analysed.¹⁵ A series of 40 cases out of 4710 at the general population were reported in children younger than 16 years from Geneva, and 8 cases were reported as case index.¹⁶ A study of households in the Netherlands reported data from 116 children 1-16y and preliminary results showed that there are no indications that children younger than 12y were the first in the family infected.¹⁷ In Ireland, no secondary school cases were detected after analysing 125 to 475 contacts of 3 detected cases in students 10-15years old before school closures on 12 March 2020; one case was asymptomatic.¹⁸ Preliminary results of study of COVID-19 IgG prevalence carried out in Spain at the general population level indicate that minors have a lower prevalence of IgG antibodies than adults.¹⁹ In this study the first results show that in children under 1 year the prevalence of IgG was 1.1% (95% confidence interval: 0.3-3.8%), between 1 -4 years= 2.2% (1.4-3.6), 5 to 9 years = 3% (2.3-4.1) and 10-14 years = 3.9% (3.1-4.9), while in the general population the prevalence of IgG was 5% (4.7-5.4).

Discussion

The results of the present review suggest that children would be asymptomatics as frequently as adults, and that a high percentage of reported cases came from family transmission. Although there are still many uncertainties, it does not appear that children are transmitters to a greater extent than adults. As previously mentioned, the drastic measures taken in the child population in several countries have probably been based on previous epidemics such as influenza,²⁰ without enough evidence of the current situation. Moreover, there are some theoretical reasons why school closures might be less effective in COVID-19 than in influenza outbreaks. A systematic review found that modelling studies of COVID-19 predict that school closures alone would prevent only 2–4% of deaths, much less than other social distancing interventions.²¹

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3 No studies were found on the subject of the present review neither from France, Italy nor the
4 United States, countries strongly affected by the pandemic. Studies from these countries to
5 date have been addressed mainly to analyse severity of identified pediatric cases, the need of
6 PICU, or immune responses in children.²²⁻²⁴ Nevertheless, the results of this review are likely to
7 be generalisable including cases from different countries. . Two of the included studies
8 analysing school contacts found a extremely low level of transmission at school.^{15, 18} Moreover,
9 other very recent published reviews show also the low role of children as a factor of
10 transmission in general.^{25, 26}
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13 Other secondary questions that come out from this review are the differences in the
14 incubation period and the evidence that children (and probably also adults) can excrete the
15 virus in feces.⁶ According to some authors asymptomatic individuals can actively shed the
16 virus. Further, the incubation period in children following exposure to the virus can range
17 upward of 24 days.²⁷ Children more often have gastrointestinal symptoms compared with
18 adults. The majority of children infected by novel CoVID-19s have a documented household
19 contact, often showing symptoms before them.⁴
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23 If children are important in viral transmission and amplification, social and public health
24 policies (eg, avoiding interaction with elderly people) could be established to slow transmission
25 and protect vulnerable populations. Nevertheless, the application of the precautionary
26 principle should be evidence-based as much as possible and try to avoid creating adverse
27 effects with potential medium and long-term negative impact on the childhood population. A
28 study analysing viral load by age in a sample of 3712 patients from Berlin found no differences
29 by age on viral loads; even in the very young patients do not differ significantly from those of
30 adults.²⁸
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33 Several limitations of the present rapid scoping review should be mentioned. The inclusion of
34 none reviewed pre-print papers, the inclusion criteria based only on one evaluation, the lack of
35 critical analysis of the risk of bias, and the inclusion of non-primary study designs may weakens
36 the attempts at understanding the data existing. However, the urgent need to understand the
37 process of transmission and the results obtained provide a reasonable evidence on the process
38 analysed. Furthermore, the results of other reviews on the process of infection in children with
39 similar results to the present study support the strength of the results obtained. Secondly, the
40 current lack of reliable, valid and comparable data on epidemiologic surveillance,²⁹ on the
41 diagnostic tests, and the scarce knowledge on the mechanism of transmission and
42 prognostic.^{30, 31} High quality epidemiological studies are necessary to solve these questions
43 with certain plausibility. On the other hand, up to date there are scarce data on the
44 socioeconomic factors and its influence on the current pandemic. Social determinants of child
45 health should be addressed to enhance the positive effects and avoid the adverse effects of
46 this pandemic on children's rights and social inequalities in children's health.³²
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Table 1. Characteristics of included studies and main results

First author / Journal	Type of study	Publication date	Country	N total population	Number of pediatric cases	Asymptomatics	Source of transmission / Observations
Cao et al. ⁶ J Formosan Med Assoc	Review of reported cases	02/26	China / Taiwan	44672 laboratory confirmed cases	Number of reported cases comparing with adult population was 0.9% for <10y, and 1.2% for 10-20y	Most showed mild symptoms. No data on asymptomatic cases	Mainly intra-familial cluster circles. Children could become the main spreader when their infection is mild /Stool could be a source of transmission
Dong et al. ⁷ Pediatrics	Epidemiology of pediatrics cases	03/17	China/ Cases recruited from the China Center for Disease Control and prevention	-	2143 pediatric cases reported; 34% onfirmed; 66% suspected	44% asymptomatics	Not confirmed but family transmission seems to be the main source of cases
Ji Young Park et al. ⁸ J Korean Med Sci	A case study. Brief report	03/16	Korea	-	A 10y old girl. 1rst case detected in Korea	Mild symptoms	Close contact of her uncle and mother who were confirmed
Hai T Le et al. ⁹ Lancet Child Adolesc Health	A case -study	03/23	Vietnam	-	3 months old girl. 1rst case of infant detected in Vietnam	Nasopharyngeal swabs positive	Contact with her grandmother who was confirmed
Lu X et al. ¹⁰	Correspondence. Serie of cases	03/18	China	Children treated	171/1391 tested were (+).	15% asymptomatic. Three patients	90% confirmed family cluster

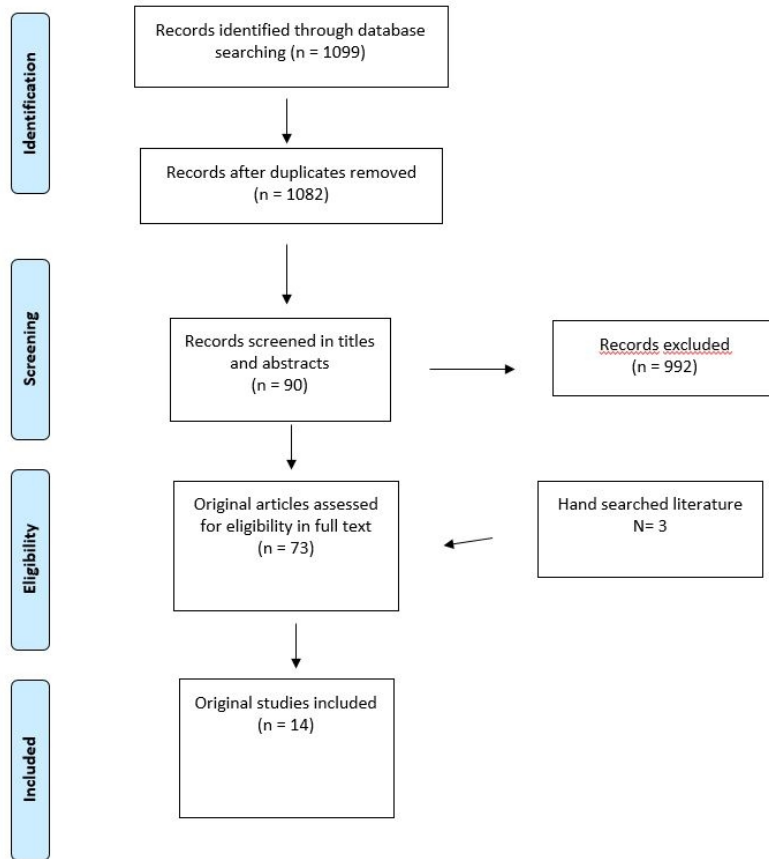
New England J Med				at the Wuhan Children's Hospital		required PICU (all with previous chronic conditions)	
Chang et al. ¹¹ J Formosan Med Assoc	Systematic review of 9 case series	02/26	China		93 cases	26% asymptomatics	75% family contact
Su L, et al. ¹² Emerg Microbe Infections	Serie of cases	03/12	China	-	9 cases from 14 families, ages 11 months to 9y	6 cases asymptomatics. The rest of children with mild symptoms and recovered after 2-3 weeks	Family transmission. Five discharged children were admitted again because their stool showed positive result in SARS-CoV-2 PCR.
Qiu et al. ¹³ Lancet Infect Dis	Serie of cases	03/25	China	N total= 616	36 cases (6%) in children.	Half of them asymptomatics	Family contact
Du W et al. ¹⁴ Infection	Serie of cases (families)	03/23	China	53 adults	14 children	8 out of 14 children asymptomatic	All cases family clusters
NCIRS ¹⁵	Reported cases from New South Wales schools.	04/26	Australia	18 cases (9 staff school members and 9 students) during March-April	9 cases of students from 10 high schools and 5 primary school	No data	863 analysed contacts of students: 1 case detected
Posfay-Barbe et al. ¹⁶ Pediatrics	Serie of cases from Geneva University Hospital	05/27	Switzerland	4710 total cases. Familial cluster evaluation	40 cases (0.9%) <16y	1 asymptomatic	8% (n=3) developed symptoms before other family members

RIVM ¹⁷	National Institute for Public Health and the Environment	05/27	Netherlands	Study in households: 239 participants, including 185 housemates. This involves 123 adults	116 children between 1 -16 years.	No data	There are no indications that children younger than 12 years old were the first in the family to be infected.
Heavey L, et al. ¹⁸ Euro Surveill	National Public Health Emergency	05/28	Ireland	Study of school contacts of 3 cases on children 10-15y before 03/12/2020	125; 222; 475 school contacts analysed, respectively	One case asymptomatic	No secondary school cases detected
Carlos III Public Health Institute ¹⁹	ENE-COVID-19 study: first wave	05/13	Spain	Study of IgG antibody in a representative sample of Spanish population (N total participant population = 60897)	8243 children <15y.	No data on available on symptoms stratified by age	Prevalence of IgG: <1 year = 1.1% (95% confidence interval: 0.3-3.8%)/ 1 -4 years= 2.2% (1.4-3.6) / 5 -9 years = 3% (2.3-4.1)/ 10-14 years = 3.9% (3.1-4 , 9) General population = 5% (4.7-5.4).

NCIRS: National Centre for immunization research and surveillance, New South Wales; RIVM: National Institute for Public Health and the Environment, the Netherlands

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Figure 1. Search flow.



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BMJ Paediatrics Open

The role of children in the transmission of the COVID-19 pandemic: a rapid scoping review

Journal:	<i>BMJ Paediatrics Open</i>
Manuscript ID	bmjpo-2020-000722.R2
Article Type:	Review
Date Submitted by the Author:	10-Jun-2020
Complete List of Authors:	Rajmil, Luis
Keywords:	Epidemiology, Virology

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3 Title:

4 **The role of children in the transmission of the COVID-19 pandemic: a rapid scoping review**
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26 **Abstract**

27 **Background** As a response to the COVID-19 pandemic most countries have adopted measures
28 of social distance, with the childhood population being one of the main focus of attention in
29 these measures.
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31 **Methods** A rapid scoping review was carried out by searching PubMed to know if children are
32 more contagious than adults, and the proportion of asymptomatic cases in children. Google
33 Scholar, and MedRxiv/bioRxiv were also searched. The time period was restricted from 1
34 December 2019 until 28 May 2020. Only studies published in English, Italian, French or
35 Spanish were included.
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38 **Results** Fourteen out of 1099 identified articles were finally included. Studies included cases
39 from China (N= 9 to 2143), China and Taiwan (n=536), Korea (n=1), Vietnam (N=1), Australia
40 (N=9), Geneva (N=40), the Netherlands (N=116); Ireland (N=3); and Spain (population based
41 study of IgG, N=8243). Although no complete data were available, between 15% and 55-60%
42 were asymptomatic, and 75-100% of cases were from family transmission. Studies analysing
43 school transmission showed children as not a driver of transmission. Prevalence of COVID-19
44 IgG antibody in children <15y was lower than the general population in the Spanish study.
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47 **Conclusions** Children are not transmitters to a greater extent than adults. There is a need to
48 improve the validity of epidemiologic surveillance to solve current uncertainties, and to take
49 into account social determinants and child health inequalities during and after the current
50 pandemic.
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54 **Keywords:** children, COVID-19; transmission

55 Number of words in the text: 1628

56 Number of words in the abstract: 225

57 References: 32

58 Tables: 1

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What is known about the subject

- The COVID-19 pandemic has changed the lives of families and children almost everywhere in the world
- Children are susceptible to COVID-19 although clinically they are present with milder symptoms compared to the elderly, and the general population
- Given the lack of effective treatment, measures taken by Governments in several countries in order implement social distances included school closure, and even in some cases children were confined to the home
- These measures, mainly following the precautionary principle, were based on the experiences of previous epidemics (i.e. influenza) where children were the main transmitters

What this study adds

- Children are not transmitters to a greater extent than adults
- Many of the reported cases in children were from family transmission, and the percentage of asymptomatic children was variable (15%-60%)
- The urgent need for improve the validity of epidemiologic surveillance to solve current uncertainties
- Measures taken should balance the potential benefits and avoid other potential adverse effects such as increasing social inequalities in children and families

Intro

The COVID-19 pandemic started in late 2019 in China has represented a substantial change in the health of the population worldwide, especially for families and children.^{1,2} This pandemic and the lack of effective treatment so far until now, highlight the need to take measures to prevent the spread of the infection. Measures adopted at the beginning of the pandemic in almost all countries were based on the available evidence of previous epidemics like influenza, where children were major transmitters of the disease, even more than adults.³ Nevertheless, it should also be taken into account the data available from the current pandemic given there are several unknown questions. In the current situation measures taken to prevent the spread of the pandemic are generally based on the precautionary principle, and these measures should balance the potential side effects with the infection itself.

In the case of children, data available seems to indicate that they are equally susceptible to presenting infectious symptoms, although less severe compared to the adult population and the elderly.⁴ At the moment there are no certainties about the possible causes of this situation. There is also insufficient information on the child population as a source of transmission of the infection. Despite this, in the majority of countries one of the first measures adopted has been the closure of schools and even in some countries, such as Spain, the house confinement of all minors was specifically decided for at least 45 days.⁵ These strict measures taken with children present some controversies given that up to date there are many uncertainties regarding these issues in the current COVID-19 pandemic.

Given this situation and the uncertainty on the transmission mechanisms, prediction of severity, the spread of infection in asymptomatic patients, or immunity after infection, a systematic scoping review of the published data was carried out to try to move forward in answering the following questions: are children more contagious than adults? Are they proportionally more asymptomatic?

Methods

A rapid scoping literature review was carried out by search in PubMed using the following terms: "coronavirus or COVID-19 or SARS-CoV-2" and "neonates or pediatric or infant or children or adolescence" and "transmission" to find reports of pediatric COVID-19. Google Scholar, MedRxiv/bioRxiv and secondary hand search have also been done. The time period was restricted to the last six months, from December the 1st 2019 and updated until 28 May 2020. Available full texts and the reference lists of the relevant studies were reviewed.

Inclusion/exclusion criteria

All studies published in English, Italian, French or Spanish related to the transmission of COVID-19 in children were included, as well as those comparing the percentage of asymptomatic patients according to age and also the source of contagion when this was possible.

Studies that did not present data on childhood population were excluded, as well as those that focused the data exclusively on the level of severity and / or hospitalizations and / or pediatric intensive care units (PICU), or the treatment. All kind of studies (case series, cohort studies, comments, Editorials, etc.) were included although the emphasis was stated on those descriptive studies of cases. It is not ruled out that there may be some duplication in the cases included. A description of the results obtained was carried out. It was not attempted to rate the quality of included studies in this Review.

Results

Of the 1099 initial titles, 73 articles were selected for reading the full text. Of these, 14 articles were finally included (Figure 1).

Table 1 shows the results of included studies. Studies reported data from China, Taiwan, Korea, Vietnam, New South Wales (Australia), Geneva (Switzerland); the Netherlands; Ireland, and Spain. Cao et al.⁶ found that 2.1% of 44672 confirmed cases were children or adolescents, mainly from intrafamilial clusters. One of the larger series also based on the report of 2143 pediatric cases from China⁷ shows that 44% were asymptomatics and the main source of transmission seems to be the family (no data available). It should be taken into account that in the latter case series only 34% of cases of COVID-19 were confirmed and 66% were suspected cases.

The first case reported from Korea⁸ (10y old) and Vietnam⁹ (3 months old) were also associated with family transmission. A study from the hospital of Wuhan addressed to pediatric patients¹⁰ found that 171 out of 1391 screened cases were positive, 15% were asymptomatic cases and 90% of confirmed cases were from family transmission. A systematic review of 9 case series included 93 cases and reported that 26% were asymptomatics, and 75% were from family transmission.¹¹ Another series of 9 cases from 14 families,¹² 36 cases (out of 616 population),¹³ and 14 children (and 53 adults)¹⁴ found that 6, 18, and 8 children were asymptomatics, respectively.

All cases in children were from family transmission. In New South Wales schools, 9 cases of students of Primary schools and High schools were reported, and one case was detected after 863 contacts analysed.¹⁵ A series of 40 cases out of 4710 at the general population were reported in children younger than 16 years from Geneva, and 8 cases were reported as case index.¹⁶

A study of households in the Netherlands reported data from 116 children 1-16y and preliminary results showed that there are no indications that children younger than 12y were the first in the family infected.¹⁷ In Ireland, no secondary school cases were detected after analysing 125 to 475 contacts of 3 detected cases in students 10-15years old before school closures on 12 March 2020; one case was asymptomatic.¹⁸ Preliminary results of study of COVID-19 IgG prevalence carried out in Spain at the general population level indicate that minors have a lower prevalence of IgG antibodies than adults.¹⁹ In this study the first results show that in children under 1 year the prevalence of IgG was 1.1% (95% confidence interval: 0.3-3.8%), between 1 -4 years= 2.2% (1.4-3.6), 5 to 9 years = 3% (2.3-4.1) and 10-14 years = 3.9% (3.1-4.9), while in the general population the prevalence of IgG was 5% (4.7-5.4).

Discussion

The results of the present review suggest that children are as likely to be asymptomatic cases as frequently as adults, and that a high percentage of reported cases came from family transmission. Although there are still many uncertainties, it does not appear that children are transmitters to a greater extent than adults. As previously mentioned, the drastic measures taken in the child population in several countries have probably been based on previous

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3 epidemics such as influenza,²⁰ without enough evidence of the current situation. Moreover,
4 there are some theoretical reasons why school closures may be less effective in COVID-19 than
5 in influenza outbreaks. A systematic review found that modelling studies of COVID-19 predict
6 that school closures alone would prevent only 2–4% of deaths. This is much less than other
7 social distancing interventions.²¹
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10 No studies were found on the subject of the present review from France, Italy or the United
11 States, countries strongly affected by the pandemic. Studies from these countries to date have
12 been addressed mainly to analyse severity of identified pediatric cases, the need of PICU, or
13 immune responses in children.²²⁻²⁴ Nevertheless, the results of this review are likely to be
14 generalisable including cases from different countries. . Two of the included studies analysing
15 school contacts found a extremely low level of transmission at school.^{15, 18} Moreover, other
16 very recent published reviews show also the low role of children as a factor of transmission in
17 general.^{25, 26}
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20 Other secondary questions that come out from this review are the differences in the
21 incubation period and the evidence that children (and probably also adults) can excrete the
22 virus in feces.⁶ According to some authors asymptomatic individuals can actively shed the
23 virus. Further, the incubation period in children following exposure to the virus can range
24 upward of 24 days.²⁷ Children more often have gastrointestinal symptoms compared with
25 adults. The majority of children infected by novel CoVID-19s have a documented household
26 contact, often showing symptoms before them.⁴
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29 If children are important in viral transmission and amplification, social and public health
30 policies (eg, avoiding interaction with elderly people) could be established to slow transmission
31 and protect vulnerable populations. Nevertheless, the application of the precautionary
32 principle should be evidence-based as much as possible and try to avoid creating adverse
33 effects with potential medium and long-term negative impact on the childhood population. A
34 study analysing viral load by age in a sample of 3712 patients from Berlin found no differences
35 by age on viral loads; even in the very young patients do not differ significantly from those of
36 adults.²⁸
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39 Several limitations of the present rapid scoping review should be mentioned. The inclusion of
40 none reviewed pre-print papers, the inclusion criteria based only on one evaluation, the lack of
41 critical analysis of the risk of bias, and the inclusion of non-primary study designs may weaken
42 the attempts at understanding the data . However, the urgent need to understand the process
43 of transmission and the results obtained provide a reasonable evidence on the process
44 analysed. Furthermore, the results of other reviews on the process of infection in children with
45 similar results to the present study support the strength of the results obtained. Secondly, the
46 current lack of reliable, valid and comparable data on epidemiologic surveillance,²⁹ on the
47 diagnostic tests, and the scarce knowledge on the mechanism of transmission and
48 prognostic.^{30, 31} High quality epidemiological studies are necessary to solve these questions
49 with certain plausibility. On the other hand, up to date there are scarce data on the
50 socioeconomic factors and its influence on the current pandemic. Social determinants of child
51 health should be addressed to enhance the positive effects and avoid the adverse effects of
52 this pandemic on children's rights and social inequalities in children's health.³²
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Table 1. Characteristics of included studies and main results

First author / Journal	Type of study	Publication date	Country	N total population	Number of pediatric cases	Asymptomatics	Source of transmission / Observations
Cao et al. ⁶ J Formosan Med Assoc	Review of reported cases	02/26	China / Taiwan	44672 laboratory confirmed cases	Number of reported cases comparing with adult population was 0.9% for <10y, and 1.2% for 10-20y	Most showed mild symptoms. No data on asymptomatic cases	Mainly intra-familial cluster circles. Children could become the main spreader when their infection is mild /Stool could be a source of transmission
Dong et al. ⁷ Pediatrics	Epidemiology of pediatrics cases	03/17	China/ Cases recruited from the China Center for Disease Control and prevention	-	2143 pediatric cases reported; 34% onfirmed; 66% suspected	44% asymptomatics	Not confirmed but family transmission seems to be the main source of cases
Ji Young Park et al. ⁸ J Korean Med Sci	A case study. Brief report	03/16	Korea	-	A 10y old girl. 1rst case detected in Korea	Mild symptoms	Close contact of her uncle and mother who were confirmed
Hai T Le et al. ⁹ Lancet Child Adolesc Health	A case -study	03/23	Vietnam	-	3 months old girl. 1rst case of infant detected in Vietnam	Nasopharyngeal swabs positive	Contact with her grandmother who was confirmed
Lu X et al. ¹⁰	Correspondence. Serie of cases	03/18	China	Children treated	171/1391 tested were (+).	15% asymptomatic. Three patients	90% confirmed family cluster

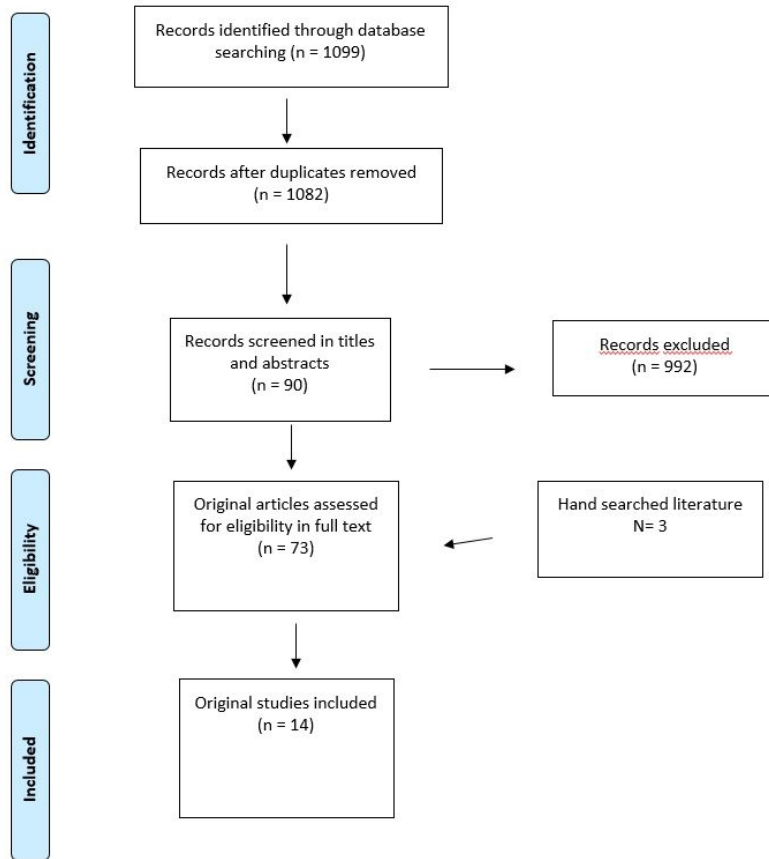
New England J Med				at the Wuhan Children's Hospital		required PICU (all with previous chronic conditions)	
Chang et al. ¹¹ J Formosan Med Assoc	Systematic review of 9 case series	02/26	China		93 cases	26% asymptomatics	75% family contact
Su L, et al. ¹² Emerg Microbe Infections	Serie of cases	03/12	China	-	9 cases from 14 families, ages 11 months to 9y	6 cases asymptomatics. The rest of children with mild symptoms and recovered after 2-3 weeks	Family transmission. Five discharged children were admitted again because their stool showed positive result in SARS-CoV-2 PCR.
Qiu et al. ¹³ Lancet Infec Dis	Serie of cases	03/25	China	N total= 616	36 cases (6%) in children.	Half of them asymptomatics	Family contact
Du W et al. ¹⁴ Infection	Serie of cases (families)	03/23	China	53 adults	14 children	8 out of 14 children asymptomatic	All cases family clusters
NCIRS ¹⁵	Reported cases from New South Wales schools.	04/26	Australia	18 cases (9 staff school members and 9 students) during March-April	9 cases of students from 10 high schools and 5 primary school	No data	863 analysed contacts of students: 1 case detected
Posfay-Barbe et al. ¹⁶ Pediatrics	Serie of cases from Geneva University Hospital	05/27	Switzerland	4710 total cases. Familial cluster evaluation	40 cases (0.9%) <16y	1 asymptomatic	8% (n=3) developed symptoms before other family members

RIVM ¹⁷	National Institute for Public Health and the Environment	05/27	Netherlands	Study in households: 239 participants, including 185 housemates. This involves 123 adults	116 children between 1 -16 years.	No data	There are no indications that children younger than 12 years old were the first in the family to be infected.
Heavey L, et al. ¹⁸ Euro Surveill	National Public Health Emergency	05/28	Ireland	Study of school contacts of 3 cases on children 10-15y before 03/12/2020	125; 222; 475 school contacts analysed, respectively	One case asymptomatic	No secondary school cases detected
Carlos III Public Health Institute ¹⁹	ENE-COVID-19 study: first wave	05/13	Spain	Study of IgG antibody in a representative sample of Spanish population (N total participant population = 60897)	8243 children <15y.	No data on available on symptoms stratified by age	Prevalence of IgG: <1 year = 1.1% (95% confidence interval: 0.3-3.8%)/ 1 -4 years= 2.2% (1.4-3.6) / 5 -9 years = 3% (2.3-4.1)/ 10-14 years = 3.9% (3.1-4 , 9) General population = 5% (4.7-5.4).

NCIRS: National Centre for immunization research and surveillance, New South Wales; RIVM: National Institute for Public Health and the Environment, the Netherlands

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Figure 1. Search flow.



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