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Review

The role of children in the transmission of SARS-CoV-2: review of the evidence and analysis of the trend of infection in the pediatric population

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Abstract

Background: The epidemiological knowledge about the diffusion and diffusibility of SARS-CoV-2 in the pediatric population is constantly updated and revised, but not always based on sound and thorough body of evidence. This study examines the trend of the virus in the pediatric population in the Italian context. Specifically, it investigates the evidence available about the role of the pediatric population in the transmission of SARS-CoV-2.

Methods: Analysis of the incidence of SARS-CoV-2 in Italy in the age group ≤ 19 years and comparison with other countries. Systematic reviews and meta-analysis available on PubMed regarding the infection rate of the pediatric population were analyzed.

Results: In the period between July 2020 and November 2020, the new cases in the pediatric population show an exponential increase, revealing a rapid growth of new infections. In the literature there is a large amount of studies about the spread and transmission of SARS-CoV-2 in the pediatric population, but only few quantitative synthesis are available. The lack of data about the secondary attack rate of a pediatric index case in primary studies combined with the frequent lack of good methods makes it difficult to determine the infection rate in children. The analyzed literature shows that: a) the majority of pediatric cases comes from family transmission; b) the index case in the clusters is predominantly adults; c) pediatric index cases appear

to be responsible for a lower secondary attack rate compared to adult index cases.

Conclusion: We observed an exponential increase of SARS-CoV-2 cases in the age group between 0 and 19 years between July 2020 and November 2020 in Italy, but the international literature indicates that children do not transmit SARS-CoV-2 more than adults. However, the evidence is not sufficient to draw firm conclusions.

Keywords

Pediatric, transmission, secondary attack rate, index case, SARS-CoV-2, Italy.

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Introduction

Since 2020, the world has been confronted with one of the most pervasive and disturbing challenges of recent decades, the pandemic caused by the new coronavirus SARS-CoV-2, which, almost 2 years after its onset, has caused over 22 million cases and more than 4.6 million deaths worldwide. In Italy, in the same period, there were over 4.5 million cases and over 129 thousand deaths [1].

Crucially, the inter-human transmissibility of the virus seems to involve asymptomatic individuals [2]. However, the epidemiological understanding of diffusion, diffusibility, and transmission modalities is still continually being updated and revised. The volume of data available to scholars and policymakers is now considerable [1-47], so much so that the management of these data is difficult, despite their importance. Complexity and relevance also affect the scientific debate concerning the role of children in the spread of the virus, which quite rapidly appeared distinct from that of adults [3]. The consideration that children are the main drivers of respiratory viral epidemics involving enteroviruses, respiratory syncytial viruses, coronaviruses, and adenoviruses [4] and the first data from China indicating a similar secondary attack rate for adults and children have led to the belief that children could be important spreaders of SARS-CoV-2 [5]. Many initiatives, including school closures, have reflected the urgent need to counter a serious threat that is, in many ways, still unknown.

Numerous observational studies and data from health surveillance have contributed to a growing body of knowledge that scholars have begun to synthesize and interpret. However, the scientific community is largely in agreement in stating that the data available on the pediatric population are generally incomplete and that the resulting evidence is not sufficiently solid. In particular, the issue of the transmissibility of the infection in the pediatric population has not yet been adequately investigated and remains unclear [6-8]. In the present study, the pediatric population is defined as that between the ages of 0 and 19 years inclusive.

Aim of the study

In order to have a synthetic picture that helps to assess the extent of the threat posed by the SARS-CoV-2 epidemic and its spread in the pediatric population, the present study has examined the trend of the virus in the pediatric population by exploring, in particular, the phenomenon in the Italian context. Furthermore, we searched, via a literature review, the available evidence on the role of the pediatric population in the transmission of SARS-CoV-2.

Materials and methods

In the first part of this work, a statistical study was conducted based on the collection and processing of the SARS-CoV-2 data published periodically by the Istituto Superiore di Sanità (ISS) in reference to the Italian context in the period from February 2020 (when the first pediatric case was reported in Italy) to June 2021 and by the WHO in reference to the global data in the period from December 2019 to June 2021. Based on the incidence of SARS-CoV-2 in Italy in the age group ≤ 19 years, a comparison was made between positive cases for SARS-CoV-2 in Italy and positive cases in other countries of the world in the same age group and for the same observation period. The reported data related to the number of positive cases in the pediatric population in Italy were extrapolated from the bulletin published by the COVID-19 Task Force of the ISS until June 30, 2021 [9], and were reworked to obtain the incidence of new cases every 15 days (Excel® software was

used to process the data and related graphs). The exponential function was calculated using the TI-84 Plus graphing calculator. In the second part of this study, a search for systematic reviews and meta-analyses was conducted to summarize the evidence on the infectivity of the pediatric population.

Methods and tools will be illustrated in detail at the beginning of each part of this research work.

Italian overview of the pandemic in the pediatric age group

In Italy, the pediatric age refers to children from birth to the age of 14 years, although pediatric care can be extended until the age of 16. However, even in the scientific literature, a reference to a time span of up to 18 years is quite frequent [10].

The revision of the ISTAT data in the Pyramid of Ages, which represents the distribution of the resident population in Italy by age and by sex, reports the age by 5-year classes and, as of January 1, 2021, shows that 3.7% of residents are from 0 to 4 years old, 4.3% from 5 to 9 years old, 4.8% from 10 to 14 years old, and, finally, 4.8% from 15 to 19 years old [11]. The first case of positivity in a pediatric individual in Italy was confirmed on February 23, 2020 [12].

As can be seen in **Fig. 1**, in the first 5 months of the epidemic, the number of new cases grew

Date	No. of cases	14/07/20	367	02/12/20	20,585	14/04/21	39041
09/03/20	128	28/07/20	428	16/12/20	30,659	28/04/21	40,380
26/03/20	812	11/08/20	861	29/12/21	23,318	19/05/21	42,765
06/04/20	684	18/08/20	768	13/01/21	31,948	26/05/21	7,815
23/04/20	1,826	01/09/20	2,416	27/01/21	28,698	09/06/21	10,055
07/05/20	1,100	22/09/20	4,403	10/02/21	29,903	30/06/21	5,286
20/05/20	613	06/10/20	4,798	24/02/21	33,751	TOT.	643,084
03/06/20	393	20/10/20	16,984	03/03/21	22,941		
16/06/20	287	07/11/20	65,302	17/03/21	53,561		
01/07/20	249	25/11/20	71,731	31/03/21	48,228		

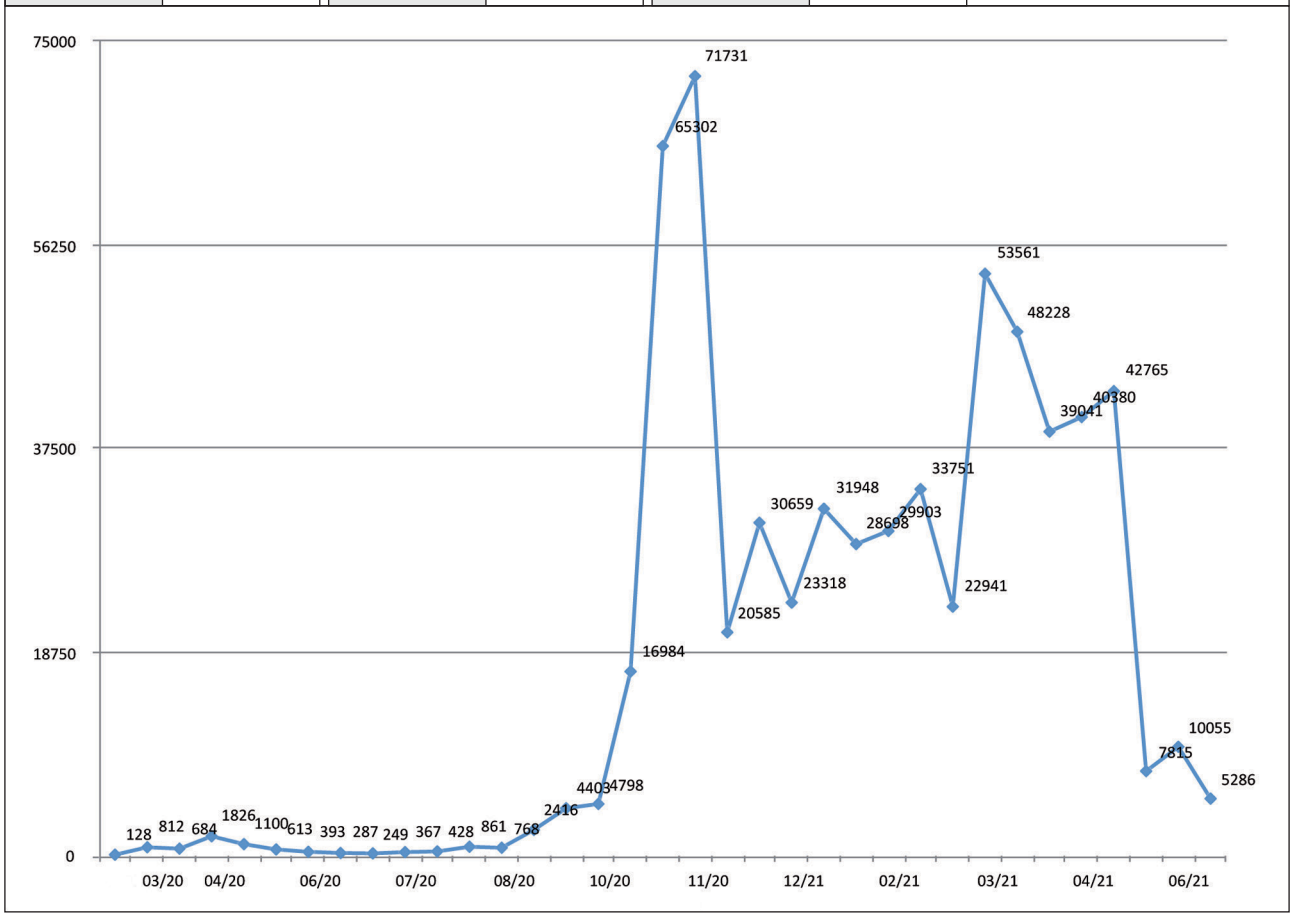

Figure 1. Trend of new cases in the population ≤ 19 years in Italy.

slowly, with the curve appearing almost flat and the incidence never reaching 2,000 new cases every 2 weeks. From the beginning of March to the end of April, the number of new cases of positive children increased by more than 14 times, from 128 (March 9) to 1,826 (April 23), reaching 1% of total cases [13]. After a decrease in the summer months, a new increase in positive cases in the age group between 0 and 19 years occurred, starting from September, with an exponential trend that peaked in November. In the period between July 2020 and November 2020, the curve steepened, reaching a peak of 71,731 new cases in the weeks between November 7 and 25.

In particular, in this period of time, the collected data follow the exponential function $y = 81.36(1.81)^x$, where the independent variable x indicates the time (divided into 15-day periods) starting from July 2020 and the dependent variable y returns the number of new cases reported as a function of time. For example, the data relating to August 11, 2020, are obtained for $x = 4$ (as this is the fourth period of time starting from 1 July), obtaining $81.36\ (1.81)^4 \approx 873$. This value is very close to the actual 861 new cases found. The data follow the reported exponential function with an accuracy of 97%. Indeed, **Fig. 2** shows how much the collected data are in line with the exponential function found, thus confirming a particularly rapid growth in new infections in that period.

As of June 30, 2021, the total number of positive cases in the age group ≤ 19 years was 643,084. In detail, the number of children in the 0-9 age group was 233,284 (5.5% of the total positive population), and 12 deaths were attributed to COVID-19 (0.009% of the total number of deaths for COVID-19).

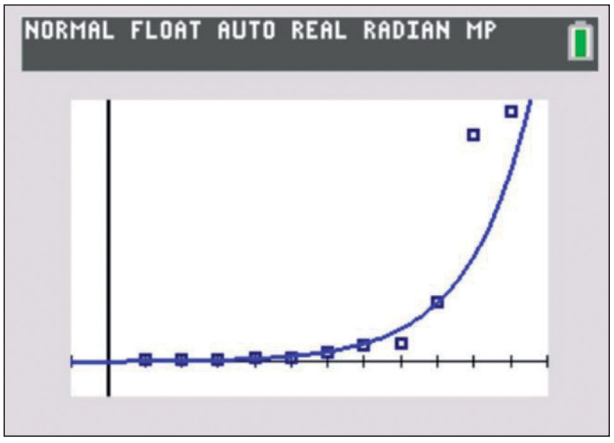

Figure 2. Adherence of the collected data (indicated with squares) with the exponential model found. TI-84 Plus graphing calculator.

Almost twice as many positive cases were recorded in the 10-19 age group (409,800), with a percentage per age group of 9.7% compared to the total positive population and 17 deaths (0.013% of the total number of deaths due to COVID-19) [9, 14]. A slightly higher number of cases was observed in males in both age groups (**Fig. 3** and **Fig. 4**). **Fig. 5** summarizes the data on the total number of cases

	No. of cases
Male 0-9 years	120,749
Female 0-9 years	112,535

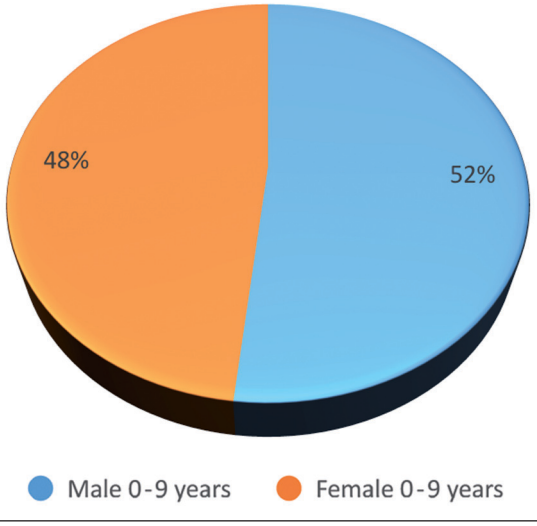

Figure 3. Number of cases by sex in the 0-9 age group in Italy as of June 30, 2021.

	No. of cases
Male 10-19 years	213,492
Female 10-19 years	196,308

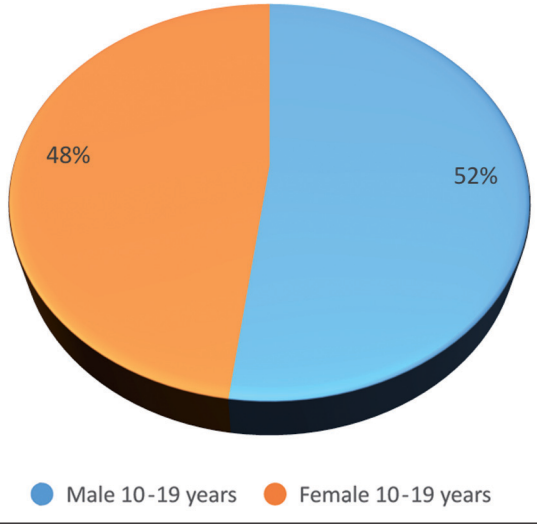

Figure 4. Number of cases by sex in the 10-19 age group in Italy as of June 30, 2021.

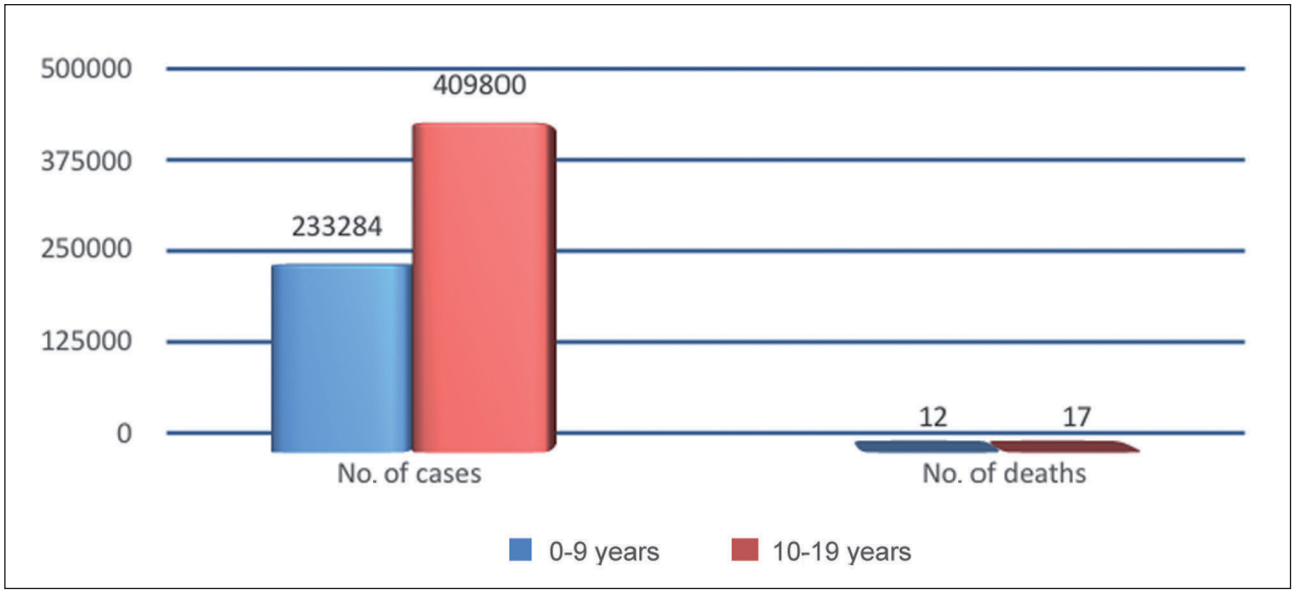

Figure 5. Total number of cases and deaths as of June 30, 2021, in Italy.

and deaths from COVID-19 diagnosed in Italy for the 0-19 age group extracted from the bulletin published by the COVID-19 Task Force of the ISS on June 30, 2021 [9].

The information on the total number of SARS-CoV-2-positive cases and deaths in the pediatric population should be contextualized by considering the data on the prevalence of the asymptomatic and paucisymptomatic trend of the infection in children, which exceeded 70% for all age groups. This is because, according to the data at our disposal, children have an asymptomatic or paucisymptomatic infection in almost 8 out of 10 cases [15]. Thus, in the first phase of the epidemic (March to May 2020) [16], when only clearly symptomatic subjects were tested, pediatric cases, both sporadic and possible outbreaks, may not have been detected or may have been underestimated, altering their real proportion of the overall population. However, with the easing of the lockdown, the systematic tracing of contacts, the use of digital tracing, and the greater diagnostic capacity, it was possible to detect a greater number of cases in the second phase of the epidemic, even asymptomatic cases [17].

A look at the pediatric population affected in other countries

Isolation of the pandemic data from the pediatric population in the international context involves, among other factors, a difficulty derived from the fact that not all countries delimit and divide the pediatric population in the same way. The different specifications of the age groups and, in particular, the differences in the specification of the upper age limit hinder the interpretation of the epidemiological data and the synthesis of the evidence of the international scientific literature, as already reported by other scholars [18].

The following are the data on the number of SARS-CoV-2 cases in the specific age group 0-19 years and the number of total cases in some of the other countries during the period from December 2019 to June 2021. The data were obtained from a review of the scientific literature, as well as with generalist data platforms and search engines, such as Statista and Google. We also drew on data reported by government sites and WHO dashboards. The data are shown graphically in **Fig. 6**.

It is clearly evident that the number of cases in the 10-19 age group is, in all of these countries, double, if not triple, the number of cases recorded in the 0-9 age group, following the trend in Italy that counted 233,284 and 409,800 cases in these respective age groups. Of the seven countries considered, Italy had the highest number of cases in the pediatric population group. Considering the relationship between the number of positive cases in this age group and the number of total cases, as can be seen in **Tab. 1**, the percentage of cases in Italy is not among the highest. In fact, Norway and Denmark recorded the highest incidence rate in the 0-19 age group with respect to the total cases, reaching 26% and 24% of total cases, respectively.

	Norway	Danmark	Belgium	Estonia	Italy	Japan	Moldova
0-9 years	11,268	21,530	47,998	5,788	233,284	24,323	5,541
10-19 years	21,589	47,763	129,484	13,585	409,800	54,629	11,154

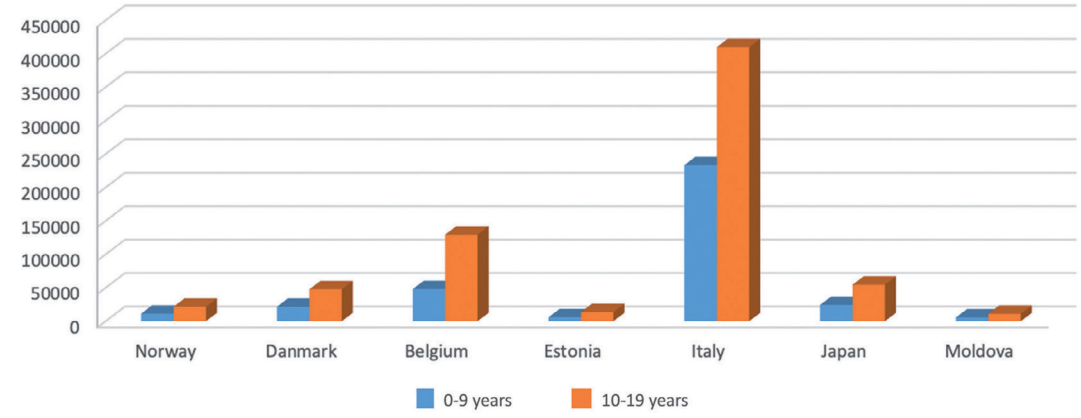

Figure 6. Number of cases by age group in various countries in June 2021.

Table 1. Percentage of the number of cases in the age group 0-19 years compared to the number of total cases in the various countries in June 2021.

Country	No. of cases (0-19 years)	No. of cases (tot.)	%
Norway	32,857	128,275	26%
Denmark	69,293	290,333	24%
Belgium	177,482	1,072,218	17%
Estonia	19,373	130,156	15%
Italy	643,048	4,242,373	15%
Japan	78,952	737,086	11%
Moldova	16,695	256,590	7%

Data extracted from: ISS, 2021 [9]; Stewart C, 2021 [42]; Stewart C, 2021 [43]; Statista Research Department, 2021 [44]; Stewart C, 2021 [45]; Sava JA, 2021 [46]; Sas A, 2021 [47].

In the analysis of these data, the different contact-tracing policies adopted in the different countries must be taken into account.

The analysis of the data conducted here confirms that the initial belief that children did not become infected [19] was not supported by adequate and reliable data. However, the discussion of their role in the spread of the virus is still open because COVID-19 infection is less defined in children and adolescents than in adults [19].

The next section reports the available evidence on the direction of transmission of SARS-CoV-2 infection in the pediatric population. Specifically, we investigated the available evidence on the infectivity rates of the pediatric population.

Infectiousness of the pediatric population: review of the literature

Methods and tools

The PubMed electronic database was interrogated using various combinations of the following keywords: infant, children, adolescent, pediatric, transmission, infectivity, secondary attack rate, transmission rate, index case, SARS-CoV-2, and COVID-19. The following filters were also applied: systematic reviews and meta-analyses published in English and Italian from December 1, 2019, to June 30, 2021. In addition, we checked the reference lists of the studies whose full texts were read to identify any relevant articles not included in the first query of the database.

Studies thus selected were included for subsequent full-text reading and data analysis only if they reported a swab-confirmed diagnosis of SARS-CoV-2 infection, the pediatric population infectivity rate or attack rates of pediatric cases, the age/age group of the index case, or the odds ratio of infection for the different age groups.

The secondary attack rate of the index case (i.e., the number of new cases infected by an index case for every 100 exposed individuals), stratified by age, allows us to determine whether children transmit SARS-CoV-2 to a greater or lower extent than adults. We excluded studies with no information on the index case or the secondary attack rates of pediatric index cases, as well as reviews that did

not have clear selection criteria and data extraction. Furthermore, studies on the vertical transmission of the infection were excluded.

Results

The database search according to the above-described criteria allowed us to identify 548 studies. We then carefully examined the titles and abstracts. In total, 78 studies were selected for full-text reading. Following this analysis, 3 reviews were selected that met the predefined inclusion and exclusion criteria.

Data extraction table

The data extraction table containing the selected reviews is shown here (**Tab. 2**) [20-22].

Table 2. Data extraction table.

Publication	Type of study	Countries and date	Study population	Results
Zhu et al., 2021 [20]	Meta-analysis of 57 case series studies, prospective and retrospective cohort studies, descriptive studies, cross-sectional studies, case studies, and retrospective observational studies. The authors do not mention any bias assessment process in the selected studies.	China, Singapore, USA, Vietnam, Malaysia, South Korea, Japan, Morocco, Italy, France, Germany, and Greece. December 2019-August 2020.	213 family clusters comprising 509 adults and 102 individuals aged 0-18 years.	8 out of 213 family clusters (3.8%) identified a pediatric index case. Pediatric index cases caused 4% (16 of 398) of all secondary cases, as opposed to 96% of secondary cases when the index case occurred in an adult. The analysis of 11 observational studies showed that secondary attack rates are lower in pediatric family contacts than in adult family contacts (risk ratio [RR]: 0.62; 95% CI: 0.42-0.91).
Xu et al., 2020 [21]	Systematic review of 5 cohort studies and 6 cross-sectional studies. The Newcastle Ottawa Scale was adopted.	France, Ireland, Singapore, and Australia. January-July 2020.	3,345 contacts. Age < 18 years.	The cohort studies showed that 22 student and 21 adult positive index cases had 3,345 contacts, including 18 transmissions. Study 1: 12 student index cases and 15 school staff index cases; 1,448 contacts: student-student transmission rate of 0.31% and student-school staff transmission rate of 0.97% (versus a school staff-student transmission rate of 1.49% and a school staff-school staff transmission rate of 4.38%). Study 2: 1 student index case, 102 contacts, 0 transmissions. Study 3: 3 student index cases, 155 contacts, 0 transmissions. Study 4: 2 student index cases, 119 contacts, 0 transmissions. Study 5: 4 student index cases, 521 contacts, 0 transmissions.
Spielberger et al., 2021 [22]	67 studies for qualitative analysis (21 for meta-analysis, and 7 studies in which the index case was pediatric). Observational, experimental studies, guidelines, commentaries, and conference abstracts. English language limit. Pre-prints included.	China, France, Switzerland, USA, Germany, Israel, South Korea, Brazil, Brunei, Chile, Spain, Italy, Greece, Iceland, Finland, India, Japan, Singapore, Taiwan, Australia, and Vietnam. December 2019-August 11, 2020.	Subdivision between pediatric and adult population without a unique caesura.	Secondary attack rate for pediatric index cases: 13.40% (95% CI: 5.7-21.1). Secondary attack rate for adult index cases: 12.32% (95% CI: 8.3-16.4).

Discussion

Although many narrative reviews have explored SARS-CoV-2 transmission in the pediatric population, few systematic reviews have reported data on infectivity in this age group. The primary studies included are often prevalence studies or retrospective studies, a feature that reflects the lack of studies analyzing the infectivity of the pediatric population or comprehensively reporting the following data: the identification and number of index cases, their age, the total number of close contacts, and the number of close contacts developing positivity to SARS-CoV-2. In fact, there are numerous reviews [23-25] in which the authors report that they did not find data on the attack rates of pediatric cases. Indeed, primary studies often only provide data on the number of pediatric index cases, defining as such those cases in which the child is the first to test positive but, apart from the percentage of pediatric index cases and index cases of nonprobabilistic sampling of adults, they provide few, if any, other data indicative of the transmission directionality. Again, in February 2021, Goldstein et al. [26] complained about a lack of studies addressing the differences in infectivity among different age groups, although they acknowledge that there are already some data indicating that infectivity increases with age. Even though the importance of knowing the directionality in the spread of the virus has been acknowledged since the beginning, factors of a different nature emerged early on, making it difficult to compare the risk of transmission of infected children with that of infected adults [27, 28]. To conduct this estimate, a single index case, adequately identified, should have been exposed at the same time as a comparable cluster of adults and children (as, for example, in a family unit). However, due to the asymptomatic course of infection in children and the difficulty in excluding a previous intra-family transmission, it is difficult to find studies capable of meeting all of these conditions. Rajmil [29], who conducted a scoping review with the aim of understanding the role of children in the transmission of SARS-CoV-2, complained about the very poor quality of the studies and, in particular, the failure to register the number of individuals who tested negative and asymptomatic among those who tested positive and the failure to identify the source of transmission. Given the numerous factors that make it difficult to understand the direction of transmission among the different age groups, there are more and more useful recommendations for producing high-quality data [30, 31].

Our search for systematic reviews that reported evidence on infectiousness in children identified only 3 systematic reviews meeting the established inclusion criteria. The 3 reviews included a total of 135 study articles conducted in 24 different countries. These primary studies were, for the most part, descriptive studies (case reports and case series) and analytical studies (both prospective and retrospective cohort studies and cross-sectional studies) and analyzed data from the first epidemic wave, a time when many states had adopted more or less severe restrictive measures. By analyzing the trend of infections within family clusters, differences in infectivity and susceptibility to infection between adults and individuals < 18 years were identified. Spielberger et al. [22] investigated the transmission of SARS-CoV-2 in reference to the pediatric population without setting restrictions, whereas the review by Xu et al. [21] examined pediatric cases in the school setting. Regarding the first context, the review by Zhu et al. [20] has the merit of starting from precise definitions and delimitations of search terms and, by starting from a stratification by age group, conducted a meta-analysis of secondary attack rates within family clusters. They identified only 8 out of 213 clusters (3.8%) in which the index case was pediatric (with a total sample of 611 individuals, including 102 pediatric individuals). Pediatric index cases were responsible for a much smaller number of secondary cases than adult index cases: just 16 out of 398, or 4%, versus 96% of secondary attacks linked to an adult index case. As well as not being able to exclude the initial limit constituted by the fact that the predominantly asymptomatic evolution of the infection in the pediatric population could have hindered the recognition of family clusters with a pediatric index case, the authors were also limited by the small number of studies that indicated the total number of infected and non-infected members of the household. The 5 clusters in which the secondary attack rate of the pediatric index case could be calculated did not allow them to determine whether children are more or less capable of transmitting SARS-CoV-2 than adults. This is a question that Spielberger et al. also attempted to answer [22]. They included a wide typology of studies that permitted a fairly complete international picture (excluding the African continent). These studies were homogeneous in terms of the incidence of cases (beginning of the first epidemic wave). In addition, because the restrictive measures were not

yet present or had just been implemented, the authors believed that they would not have significant effects. Their meta-analysis included 11 contact tracing studies that exhibited high heterogeneity ($I^2 = 97.7\%$) and excessive confidence intervals (secondary attack rate from pediatric index cases versus the attack rate from adult index cases: 13.40% [95% CI 5.7-21.1] versus 12.32% [95% CI 8.3-16.4]). The authors concluded that the analysis of the selected literature did not allow them to identify evidence of significant differences in the infectiousness of adults and children. However, while taking into account the various factors possibly influencing the availability of reliable data, the fact that infected children are often asymptomatic or paucisymptomatic and therefore that there is a risk that they will not be identified as index cases (an issue already raised by Zhu et al. [26] and many other scholars), Spielberger et al. [22] affirm that the few outbreaks in kindergartens and the low rates of positivity in the pediatric population versus the adult population, also emerging from second wave data, suggest that children are not the feeders of the spread of the epidemic. Even Xu et al. [21] found only 11 studies that could answer their question on the transmission of SARS-CoV-2 in schools, but there were just 5 cohort studies in which they were able to compare the transmission rate of students with that of school staff. The data are too limited to allow a quantitative synthesis that represents the spread of the epidemic in schools and the probability of students passing the infection to others. The authors' considerations relate to the fact that the paucity of evidence reflects the low number of outbreaks in the school setting (referring to the first wave) and that the various transmission prevention measures were most likely effective. However, more recently, other authors have argued for different positions. Warner et al. [32] noted that a comparison of the trend of positivity in the pediatric population with the open-close cycles in schools in the UK suggests that children and adolescents play a role in the transmission of SARS-CoV-2 in schools, households, and the general population.

In summary, the 3 reviews that we selected suggest that, in 2020, (1) most pediatric cases who tested positive for SARS-CoV-2 were due to family transmission; (2) the index case in the clusters was predominantly an adult; and (3) pediatric index cases appear to have a lower secondary attack rate than adult index cases.

Additionally, other general considerations can be made based on our review. First, the data already judged by the authors of the selected reviews, although insufficient and invalidated by the methodological limitations of the primary studies, allow a very approximate understanding of the transmission of the virus in the pediatric population and, above all, of the infectivity of individuals in this age group. The main reasons for the lack of data on the infection transmission ability of the population under 19 years are as follows: (1) the high likelihood of a failure to diagnose infection in this age group due to generally not severe clinical manifestations (with an underestimation of the rate of asymptomatic infected children also reported by more recent studies) [38]; (2) the lockdown measures that, in various countries, involved the closure of schools; and, finally; (3) the hypothesis that children and young people have reduced sensitivity to infection. However, the actual weight of these factors, both individually and together, remains to be established. Even the most recent literature reports conflicting and inconclusive evidence on the infectivity of the pediatric population [33]. Paul et al. [34], in their cohort study conducted in Canada (132,232 cases in 191 families, 6,280 pediatric [< 18 years] index cases, and a resulting secondary attack rate in 27.3% of cases), found that younger children have a greater probability of transmitting SARS-CoV-2 infection than older children.

A trend toward less infectivity in the pediatric population (< 18 years) is noted in the review by Goldstein et al. [35], which reported the odds ratios of infection of contacts of individuals < 18 years of 4 studies (in addition to an Israeli study that estimated the relative infectivity of individuals < 20 years). The authors of this review also complained of poor data quality that hindered their analysis (primarily, differently grouped age groups, different definitions of "contact", and different contact-tracing procedures).

A strong lack of solid evidence therefore persists, even almost 2 years from the beginning of the pandemic, during which containment measures, including severe ones, have been implemented [6].

Study limitations

The limitations of our study reflect the fact that we searched only one database, albeit the most consulted database by healthcare professionals, and that we did not assess the risk of bias of the selected reviews. Many contact-tracing studies included in the systematic reviews examined were conducted during lockdown periods and this may have distorted the data because contacts outside the

family were limited by the extent of the confinement (thereby unbalancing the comparison with family contacts). For this reason, the conclusions of this study are provisional and should be taken with caution. A difficulty facing this study was that the various authors used different definitions of the pediatric age group and differently subdivided the groups, complicating data comparisons. It should also be noted that the fact that many studies take as the index case of a cluster the first member of the group (family or school) to develop the symptoms represents a startling assumption that requires verification; in fact, the first to develop symptoms is not necessarily the first to be infected, as already noted by other authors [36, 37]. It is also necessary to keep in mind another consideration, increasingly evident with the evolution of the epidemic and the constant updating of epidemiological data: the results of the studies examined in this work mainly refer to the first epidemic wave and to the variant of the virus then present and widespread, reflecting the contexts in which the primary studies were conducted. The evolution of the pandemic and the appearance of new variants of the virus have led to significant changes in the transmissibility and spread of the virus in the different population groups, and it seems that there is an increased incidence of infection in the pediatric population, also in Italy, even if the data are still insufficient to draw conclusions [38]. Another factor destined to affect the scenario studied is the implementation of the vaccination campaign, which began in Italy in the early months of 2020 and has also been available for children up to 12 years of age from summer 2021. In any case, the urgency and need to understand the role of children in the transmission of the virus constitute the context and the reason why we offer this work as a stimulus for further study and reflection.

Conclusions

This study is a survey of the data and evidence available on the spread of SARS-CoV-2 in the pediatric population, with particular attention paid to the Italian situation. The first studies conducted since the onset of the COVID-19 pandemic showed that children were less affected than adults in terms of disease severity and frequency of cases. It was also already known that most pediatric cases had been registered within family clusters. Against the background of this fairly homogeneous presentation provided by the literature, some scholars had reported a poor documentation of the directionality of the transmission of the virus with respect to the pediatric population and therefore a lack of solid evidence on the role of children in the transmission of SARS-CoV-2.

Our study confirms and updates this assessment of the available literature. In addition to a detailed presentation of the international literature, our study compares Italian data with those of other countries and presents a statistical analysis of Italian data that identifies an exponential function describing the particularly rapid growth of new SARS-CoV-2 cases in the age group between 0 and 19 years between July 2020 and November 2020 [39].

The present study allows us to state that children do not appear to transmit SARS-CoV-2 to a greater extent than adults; however, the literature review shows that there is insufficient evidence to draw firm conclusions. This represents a serious shortcoming because the restriction measures imposed to contain the pandemic and, in particular, the closure of schools should be, even almost 2 years from the beginning of the pandemic, supported by scientific evidence that justify its maintenance and value, without forgetting their serious direct and indirect repercussions. This is a not insignificant aspect that has already been discussed in the literature [40, 41].

Declaration of interest

The Authors declare that they have no conflict of interest. The Authors declare that they have not received any funding for this article.

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