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UNIVERSITAT AUTÒNOMA DE BARCELONA

Facultat de Medicina

Departament de Pediatria, d'Obstetrícia i Ginecologia i de Medicina Preventiva i Salut Pública

Doctorat en Metodologia de la Recerca Biomèdica i Salut Pública

Doctoral thesis

**SARS-CoV-2 infections and its determinants among
students in a setting of Sentinel Schools from Catalonia,
Spain.**

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Doctorat en Metodologia de la Recerca Biomèdica i Salut Pública

**Thesis presented by Fabiana Ganem to obtain the Degree of
Doctor in Medicine**

Director: Dr. Jordi Casabona i Barbarà



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ABBREVIATIONS

SSNC - Sentinel School Network Study Group of Catalonia

COVID-19 - Coronavirus Disease 2019.

RT-PCR - Reverse Transcriptase Polymerase Chain Reaction.

RAT – Rapid Antigen Test.

IgG – Immunoglobulin G

IgM – Immunoglobulin M

PHE - Public Health Emergency

VOC - Variant of Concern

PHEIC - Public Health Emergency of International Concern.

CSSNC: The COVID-19 Sentinel Schools Network of Catalonia.

SARS-CoV-2 - Severe Acute Respiratory Syndrome Coronavirus 2.

SARS-CoV - Severe Acute Respiratory Syndrome-Related Coronavirus.

MERS-CoV - Middle East Respiratory Syndrome-Related Coronavirus.

WHO - World Health Organization.

SAGE - Strategic Advisory Group of Experts on Immunization

ICU - Intensive Care Unit.

R/R0 - Reproduction Number.

R(t) - Time Dependent Reproduction Number.

EMA - European Medicines Agency.

HCW – Health Care Workers

CEEISCAT - Centre d'Estudis Epidemiològics Sobre Infeccions De Transmissió Sexual y el VIH/SIDA de Catalunya.

SCG - Stable Coexistence Groups.

CI - Confidence Interval.

RR - Relative Risk.

PR – Prevalence Rate.

IR - Incidence Rate

I – Incidence

AR – Attack Rate

RR - Rubin's Rules.

DSA - Deletion Substitution Addition.

RMSE - Root Mean Square Error.

GLMM - Binomial Generalized Linear Mixed Models.

AIC - Akaike Information Criterion.

OR: Odds Ratio.

ORa: Adjusted Odds Ratio.

SD: Standard Deviation.

LCA - Latent Class Analysis.

COSMO - COVID-19 Snapshot Monitoring.

CASPE - COVID-19 Adolescent Symptom and Psychological Experience

AquAS - Agència de Qualitat I Avaluació Sanitàries de Catalunya.

SISAP - Primary Care Services Information System.

PADRIS - Data Analytics Program for Health Research and Innovation.

DGRIS - Direcció General de Recerca i Innovació en Salut.

ICS - Institut Català de la Salut.

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ABSTRACT

The Sentinel Schools Network of Catalonia project was designed to monitor and evaluate the scenarios related to COVID-19 public health emergency in Catalonia's school population, gathering evidence to inform health and education protocols to control of SARS-CoV-2 infection in schools, and as part of this plan, monitoring the vaccine acceptability, compliance of public health measures and the impact of the pandemic in adolescents' psychological wellbeing. In addition, was implemented a pilot study to monitoring influenza-like illness through syndromic surveillance for children aged 6-11 years.

This doctoral thesis aimed to estimate occurrence of SARS-CoV-2 identifying their determinants among students and school staff during different phases of the pandemic, monitoring vaccination rates, investigate the key reasons and determinants associated with COVID-19 vaccine hesitancy among the students and parents and evaluate the impact of the pandemic on the adolescents psychological wellbeing, describing coping strategies adopted to manage the health crisis and their association with self-perceived mental health.

We performed a cross-sectional and longitudinal studies. We collected data about sociodemographic and epidemiologic characteristic, contact patterns, knowledge, attitudes and behaviors regarding COVID-19, vaccine acceptance and mental health aspects through a self-applied questionnaire and we perform antibody and antigen rapid tests for SARS-CoV-2 detection using blood and nasal samples. Were included 4,533 students and 1,158 school staff from 23 schools. We describe the results stratified by age group and sex and adjusted by aged and school. Univariate and multivariate logistic regression models, logistic mixed models, a Latent Class Analysis and a Deletion Substitution Addition, a machine learning algorithm were performed.

The initial crude SARS-CoV-2 seroprevalence was 14.8% and 22% and active infection prevalence was 0.7% and 1.1% for students and staff respectively. The incidence was 2.73 per 100 person-month. Socioeconomic, self-reported knowledge, risk perceptions and contact pattern variables were positively associated with SARS-CoV-2 infections. Close contact was a risk factor while highest socioeconomic status level and compliance with sanitary measures was protective. The vaccination rate

against COVID-19 reached 70.8% in students under 16 years and 95.8% in students over 16 years at the end of the study project. The acceptability among unvaccinated students was 40.9% and 20.8% in October and January, respectively. The key reason to vaccine hesitancy were concern about side effects, insufficient research, rapid development, necessity for more information, previous infection, risk perception and use of alternative therapies as homeopathy. The impact of COVID-19 in mental health was higher in girls than boys, 36.9% and 17.8%, respectively, and the main emotions reported were worried and boredom. Positive coping strategies was associated with less adverse mental health among girls, whereas unhealthy habits were associated with worsening of mental health for both girls and boys. In the pilot study were registered 189 school absence, 62 of them (32.8%) related to health reasons. Subgroups of influenza-like illness were founded such as a significantly and positively association with school absences.

The major contribution of this study was to provide evidence about the transmission dynamic of SARS-CoV-2 and evaluate the sanitary protocols implemented avoid spread in schools. This evidence was useful to keep the schools open safely. In the same way monitoring vaccine hesitancy among adolescents, children and their parents has been important to understand how act different multilevel determinants. This study also demonstrated the negative impact of the pandemic on adolescents and especially on girls, and this monitoring are useful to improve development of healthy coping strategies during health crises like COVID-19, including new perspective as gender in future interventions. Finally, the findings of the syndromic pilot study could help us to understand reasons to school absences, offering an opportunity for quick action, or simply for monitoring school health situation.

Key words: SARS-CoV-2, COVID-19, epidemiological studies, longitudinal studies, cross-sectional studies, school, pandemic, public health surveillance, adolescent health, child health, psychological well-being, vaccination hesitancy.

RESUMEN

El proyecto Red de Escuelas Centinela de Cataluña fue diseñado para monitorear y evaluar los escenarios relacionados con la emergencia de salud pública COVID-19 en la población escolar de Cataluña, recopilando evidencia para informar los protocolos de salud y educación para el control de la infección por SARS-CoV-2 en las escuelas. Como actividades, se monitoreó la aceptabilidad de la vacuna, el cumplimiento de las medidas de salud pública y el impacto de la pandemia en el bienestar psicológico de los adolescentes. Además, se implementó un estudio piloto para monitorear enfermedades similares a la influenza mediante vigilancia sindrómica en niños de 6 a 11 años.

Esta tesis doctoral tuvo como objetivo estimar la ocurrencia de SARS-CoV-2 identificando sus determinantes entre los estudiantes y personal durante las diferentes fases de la pandemia, monitorear las tasas de vacunación entre los participantes del estudio, investigar las razones clave y los determinantes asociados con las dudas sobre la vacuna COVID-19 y evaluar el impacto en el bienestar psicológico de los adolescentes por identidad de género, describiendo las estrategias de afrontamiento adoptadas para gestionar la crisis de salud y su asociación con la salud mental autopercebida.

Se realizó un estudio transversal y longitudinal. Recopilamos datos sobre características sociodemográficas y epidemiológicas, contactos, conocimientos, actitudes y comportamientos respecto al COVID-19, aceptación de la vacuna y aspectos de salud mental a través de un cuestionario autoaplicado y realizamos pruebas rápidas de anticuerpos y antígenos para la detección del SARS-CoV-2 mediante muestras de sangre y nasales. Se incluyeron 4.533 estudiantes y 1.158 personal escolar de 23 escuelas. Describimos los resultados estratificados por grupo de edad y sexo y ajustados por edad y centro educativo. Se utilizaron modelos de regresión logística univariados y multivariados, modelos logísticos mixtos, un análisis de clases latentes y una adición por eliminación y sustitución, un algoritmo de machine learning.

La seroprevalencia bruta inicial del SARS-CoV-2 fue del 14% y 22% y la prevalencia de la infección activa fue del 0,7% y 1,1% para los estudiantes y el personal, respectivamente. La incidencia general fue de 2,73 por 100 personas. Las variables socioeconómicas, de conocimiento, percepción y contactos de riesgo se asociaron

positivamente con las infecciones por SARS-CoV-2. El contacto estrecho fue un factor de riesgo, mientras que el nivel socioeconómico más alto y el cumplimiento de las medidas sanitarias fueron protectores. La tasa de vacunación contra la COVID-19 alcanzó el 71% en estudiantes menores de 16 años y 96% en estudiantes mayores de 16 años. La aceptabilidad entre los estudiantes no vacunados fue del 41% y 21% en octubre y enero, respectivamente. La preocupación por los efectos secundarios, el rápido desarrollo, necesidad de más información, infección previa, percepción de riesgo y el uso de terapias alternativas como la homeopatía impactaron más sobre la decisión de vacunarse. La COVID-19 impactó más en la salud mental de las niñas en relación con los niños, 37% y 18%, respectivamente. Las principales emociones reportadas fueron la preocupación y el aburrimiento. Las estrategias de afrontamiento positivas se asociaron con una mejor salud mental entre las niñas, mientras hábitos poco saludables se asociaron con su empeoramiento tanto para las niñas como para los niños. En el estudio piloto se registraron 189 ausencias escolares, 62 de ellas (33%) relacionadas con motivos de salud. Se encontraron subgrupos de enfermedades similares a la influenza, con una asociación significativa y positiva con las ausencias escolares.

El mayor aporte de este estudio fue reunir evidencia sobre la dinámica de transmisión del SARS-CoV-2 y sobre la eficacia de los protocolos sanitarios implementados en las escuelas. Estas evidencias fueron útiles para garantizar el funcionamiento seguro de las escuelas. Monitorear la reticencia a las vacunas entre adolescentes, niños y sus padres ha sido importante para comprender cómo actúan los diferentes determinantes multinivel. Este estudio también demostró el impacto negativo de la pandemia en los adolescentes y especialmente en las niñas, y este seguimiento es útil para mejorar el desarrollo de estrategias de afrontamiento saludables durante crisis de salud como la COVID-19, incluyendo una nueva perspectiva de género en futuras intervenciones. Finalmente, los hallazgos del estudio piloto se pueden aplicar para comprender las razones de las ausencias escolares, ofreciendo una oportunidad para una acción rápida o simplemente para monitorear la situación de salud escolar.

Palabras clave: SARS-CoV-2, COVID-19, estudios epidemiológicos, estudios epidemiológicos, estudios transversales, escuela, pandemia, vigilancia en salud pública, salud del adolescente, salud infantil, bienestar psicológico, Vacilación a la Vacunación.

SUMMARY

This study was developed within the framework of the COVID-19 Sentinel Schools Network of Catalonia¹ (CSSNC) project, as a part of the Coronavirus Disease 2019 (COVID-19) monitoring and evaluation plan from the Health Department of Catalonia, that was designed to monitor and evaluate the epidemiology of COVID-19 in Catalonia, gathering evidence to inform the development of health protocols and public health interventions to prevent and control of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infection in schools.

The SARS-CoV-2 emergency affected health systems globally, compelling governments to implement strategies, like social distancing or confinements, and generating stress, anxiety, and depression which impacted the population well-being, and young people. In educational settings, measures such as suspending classes and accelerating the use of technology for learning, had an impact on the routines of students and their families, and, additionally, social distancing reduced the interpersonal interactions and leisure activities of adolescents, who lost social relations with peers, amongst other changes. Several studies have shown gender differences in the response of adolescents to the COVID-19 pandemic, with a worse effect on psychological well-being observed in girls. The pandemic highlighted gender differences in mental health that reflect the distinct social processes for youth with different gender identities, as well disparities in mental health that emerge and intensify during this stage of life.

Prevalence and incidence studies are useful to analyze the transmission dynamic of SARS-CoV-2 and evaluate the associations between sanitary protocols implemented, and measures to avoid SARS-CoV-2 spread in schools. Vaccine hesitancy, defined as a delay in acceptance of vaccines despite its availability caused by many determinants, and can be influenced by many factors such as the lack of offer, communication and confidence, commonly observed with vaccine candidates. Understand determinants that affect the decision to vaccinate against SARS-CoV-2 may help to guide strategies to avoid severity and mortality by COVID-19, and that could prevent the resurgence of an others vaccine preventable disease.

This thesis gather three main studies whose main objectives were to estimate the prevalence and incidence of SARS-CoV-2 infections and to identify their determinants

¹ www.escolessentinella.org

among students and staff, to investigate the key reasons, determinants and characteristics associated with COVID-19 vaccine hesitancy among students and parents and to describe the impact of the COVID-19 pandemic on the psychological well-being of adolescents in Catalan schools by gender identity comparing coping strategies adopted to manage the health crisis and their relationship with the self-perceived impact of COVID-19 on mental health. An additional pilot study aims to evaluate a strategy of syndromic surveillance designed for children aged 6-11 years to investigate the association between respiratory syndromes and school absence.

For assess the prevalence and incidence of SARS-CoV-2 infections, we performed a cross-sectional and longitudinal studies using a questionnaire to collect nominal data and rapid tests for SARS-CoV-2 antigen and antibody detection. Regarding the vaccine hesitation study, we collected data through a questionnaire and proceed a univariate and multivariate analysis using a Deletion Substitution Addition (DSA) machine learning algorithm. For evaluate the association between coping strategies and self-perceived impact of the pandemic on mental health, we proceed a multivariate logistic regression models using data collected through a questionnaire, and, finally, for the Syndromic Surveillance approach, data collection was made by self-applied survey to collect daily health status and symptoms. We proceed logistic mixed models and a Latent Class Analysis to investigate associations with syndromes and school absence.

The crude seroprevalence measured between February and March 2021 was 14.8% (95% CI: 13.1–16.5) and 22% (95% CI: 18.3–25.8) for students and staff respectively, and the active infection prevalence measured in April 2021 was 0.7% (95% CI: 0.3–1) and 1.1% (95% CI: 0.1–2). The overall incidence for persons at risk was 2.73 per 100 person-month and 2.89 and 2.34 per 100 person-month for students and staff, respectively. Socioeconomic, self-reported knowledge, risk perceptions and contact pattern variables were positively associated with the outcome while sanitary measure compliance was negatively associated, the same significance trend was observed in multivariate analysis. In the longitudinal component, epidemiological close contact with SARS-CoV-2 infection was a risk factor for SARS-CoV-2 infection while the highest socioeconomic status level was protective as was compliance with sanitary measures.

The Vaccination against SARS-CoV-2 among the students reached 36.1% for students under 16 years and 92.4% for students over 16 years in October 2021, increasing to 70.8% and 95.8% <16y-old and >16y-old, respectively, in January 2022. The acceptability among unvaccinated students was 40.9% and 20.8% in October and January, respectively, and among parents was proportionally higher among students aged 5–11 (70.2%) in October and aged 3–4 (47.8%) in January. The key reason to not vaccinate themselves, or their children, were concern about side effects, insufficient research about the effect of the vaccine in children, rapid development of vaccines, necessity for more information and previous infection by SARS-CoV-2. For students, risk perception and use of alternative therapies were associated with refusal and hesitancy. For parents, the age of students, sociodemographic variables, socioeconomic impact related to the pandemic, and use of alternative therapies were more evident.

Regarding the impact of the COVID-19 pandemic on the psychological well-being of adolescents, a greater proportion of girls perceived a worsening in mental health than boys due to 54 COVID-19 (36.9% and 17.8%, respectively). The main emotions reported for both girls and boys were worried and boredom. We found an association between positive coping strategies with less adverse mental health among girls, whereas unhealthy habits were associated with a higher probability of declaring worsening of mental health for both girls and boys demonstrating the negative impact of the COVID-19 pandemic on psychological well-being in adolescents and a clearly worse impact on girls.

In the Syndromic Surveillance were enrolled 135 students (2163 person-days) that filled 1536 surveys. Illness was reported by 60 participants (29.52 by 100 person/day) and were registered 189 absence events, 62 of them (32.8%) related to health reasons. Subgroups of influenza-like illness were founded such as a significantly and positively association with school absences.

These studies described the exposure to the SARS-CoV-2 virus in the school environment, as well as providing important information to evaluate the implementation of policies for the prevention and control of infection by SARS-CoV-2 and other respiratory viruses in the school environment and to contribute to decision making. on improvements in the strategy to avoid the massive closure of schools with the devastating effects that this has on society, especially on children. One of the

strengths of this research is the real-time surveillance of COVID-19 cases, monitoring and evaluation of the health measures implemented by schools and their impact on the occurrence of COVID-19 in the school system.

The findings and conclusions from the studies were contributed to improve knowledge on COVID-19 occurrence among students and school staff from Catalonia. Our results showed important characteristics about the epidemiology of the SARS-CoV-2 virus in the pediatric population, also pointing out the feasibility of preventive measures as screening and vaccination and social impacts, that were presented in several instances as the objective of increasing health resources for this population. This work was supported by the Health Department of the Government of Catalonia with no grant number.

INTRODUCTION

Covid-19 Public Health Emergency Surveillance

In January 2020, China reported an outbreak of pneumonia of undetermined origin to the World Health Organization (WHO) in Wuhan City, Hubei Province. Initially, 44 cases were reported with common exposure, a seafood market in Wuhan. After initial cases were reported, an increasing number of secondary cases were detected across China. Imported cases, with evidence of transmission, have also been detected in several countries, but without evidence of sustained viral circulation outside China (World Health Organization, n.d.; 2020b).

On January 30, 2020, the WHO declared the COVID-19 outbreak a PHEIC, the Organization's highest alert level, as provided for in the International Health Regulations, this being , the sixth² time WHO declares a PHEIC, status maintained until early May 2023 (WHO 2023). Considering the progressive increase in the number of cases sustaining transmission, the world began to prepare for the possibility of a pandemic, which was eventually declared by the WHO on March 11, 2020 (World Health Organization, n.d.; World Health Organization (WHO) 2020; World Health Organization 2020a). Three years since the declaration of the COVID-19 pandemic, around 670 million cases and 6.8 million deaths were reported worldwide (Dong, Du, and Gardner 2020).

Spain declared a national public health emergency by COVID-19 on March 14, 2020 through Royal Decree 463/2020, a situation that lasted until June 21, 2020 (España 2020; RNVE 2023). The first confirmed case in the country was on January 31, 2020, and the first death on February 13 of the same year, and on February 26, the first case of community transmission was confirmed. (Generalitat de Catalunya 2022b; 2022a). As of June 2023, Spain registered more than 13 million accumulated cases and 119 thousand deaths (Dong, Du, and Gardner 2020). In Catalonia were registered 2,667,357 accumulated cases, 118,860 hospitalizations and 28,327 deaths (Generalitat de Catalunya 2022b).

The national surveillance strategy from March 28, 2022, indicates that microbiological diagnosis must be carried out in people aged 60 or over and in all hospitalized and

² Public Health Emergency of International Concern prior to COVID-19: April 25, 2009 - H1N1 Pandemic, May 5, 2014 - International spread of poliovirus, August 8, 2014 - Ebola outbreak in West Africa, February 1, 2016 - Zika virus and increase in cases of microcephaly and other birth defects, May 18, 2018 - Ebola outbreak in the Democratic Republic of Congo.

vulnerable people of any age, in contrast to the beginning of the pandemic, when surveillance was based on universal notification of all confirmed cases (RNVE 2023).

In Catalonia, an autonomous community from Spain with 7.1 million inhabitants, the 5,492 schools were closed on 13 March 2020 affecting about 1.5 million students and more than 100 thousand teachers and school staff. The schools were reopened on 14 September 2020, immediately after the school vacations, between June and August, remaining closed, therefore, for six months (Perramon et al. 2021).

The focus of health protocols developed for educational centers was early detection and isolation, including close contacts (Generalitat de Catalunya, 2020). According to this protocol developed by the government of Catalonia, in case of a Reverse Transcriptase Polymerase Chain Reaction (RT-PCR) or Rapid Antigen Test (RAT) result, a 10-day quarantine protocol is applied for the group and people who had close contact within 48 hours before the onset of the symptom or sample collection, or PCR result (for the asymptomatic) of the confirmed case. To close contacts it is advisable to perform a RT-PCR at the school or by the primary health care teams. In addition, non-pharmacological prevention measures were applied that include social distancing, use of masks from 6 years of age, frequent hand washing, natural ventilation of classrooms, entrances and exits of centers, grouping of students in stable coexistence groups (or bubble groups) and PCR screening (Generalitat de Catalunya, 2020a; 2020b).

The sanitary protocol to control the SARS-CoV-2 transmission at the schools environment were developed by the Government of Catalonia based on early detection and isolation as well implementation of public health measures as natural ventilation of classrooms, stable coexistence groups (SCG or bubble groups) and targeted screening (Generalitat de Catalunya. Departament de Salut. 2020; Generalitat de Catalunya. Departament d'Educació 2020), also monitoring COVID-19 risk factors, determinants, transmission dynamics, preventive measures compliance and outbreaks in the school to provide evidence to improve the safety of schools preventing further closures and their impact through the work packages of the CSSNC project.

The society was faced other previous outbreaks caused by emerging viral zoonotic disease, such as Severe Acute Respiratory Syndrome-Related Coronavirus (SARS-

CoV) in 2003 and Middle East Respiratory Syndrome-Related Coronavirus MERS-CoV in 2012 (Ibrahim 2020), another highly pathogenic coronaviruses, were related to epidemic amplification phenomena (Drosten et al. 2003; Zhong et al. 2003). In these outbreaks, few cases were responsible for a disproportionately high number of secondary cases, the so-called super spreaders, with an important participation of transmission in hospital environments (Varia et al. 2003; Oboho et al. 2015; Jeong et al. 2016), although COVID -19 has significant differences compared to MERS-CoV and SARS-CoV, in just over a month of the epidemic, more cases of COVID-19 have been confirmed than in the entire history of SARS-CoV and MERS-CoV. As COVID-19, at the beginning of the MERS and SARS epidemic, for example, a few number of cases were responsible for a high number of secondary cases, which allowed the occurrence of outbreaks even in scenarios with R close to one (Chowell et al. 2015; Cowling et al. 2015).

The last major pandemic was occurred in 2009, caused by the H1N1 influenza virus, where an estimated 12,800 deaths worldwide occurred in the first year of worldwide circulation (Bellei and Melchior 2011). Influenza viruses, despite the differences in relation to the viruses of the coronavirus family, have similarities regarding the mode of transmission and associated clinical syndromes. Eventually, new flu viruses originating from genetic recombination in animals infect humans and transmit in the population and were responsible for large-scale pandemics in the past, with the occurrence of hundreds of thousands of cases and thousands of deaths worldwide (Kilbourne 2006; Potter 2001).

One of the keys to response to COVID-19 Public Health Emergencies (PHE) was the introduction of public health measures to minimize the transmission and decrease in the Reproduction Number (R) (Ingelbeen et al. 2021). The time dependent reproduction number, $R(t)$, is a power indicator commonly used for infectious diseases monitoring, indicating the average number of new infections caused by an infected individual in an epidemic process (Jorge et al. 2022). The Reproduction Number, however is not static, during the course of an epidemic, the value of R can change as intervention such as tracking and isolating cases and contacts, and changes in population behavior, such as mandatory use of masks and social distancing measures are implemented, (Van Den Driessche and Watmough 2002; J Wallinga and Lipsitch 2007; Jacco Wallinga and Teunis 2004).

In this way, after a persistent increase in R , measures such as wearing face masks, closing schools and businesses, physical distancing, restricting travel, improving air ventilation, contact tracing, isolation of cases could be applied by individuals and institutions. Although this resource has been used against influenza pandemic, the COVID-19 pandemic brought a new scale and duration of these interventions provoking deepest impacts on the social behavior globally (Enria et al. 2021; Hellewell et al. 2020). The phases of decline reflected public health measures, which correspond to changes in the individual behavior of the population over time. Intervention measures such as the isolation of cases and changes in the behavior of the population can generate changes in R throughout the epidemic. However, at the beginning, R_0 values above 2.5, the occurrence of asymptomatic infection and late social distancing significantly reduced the chances of interrupting the outbreak. It is possible that new R elevations occur, triggered by amplifying phenomena, leading to new peaks epidemic. Similar behavior has been previously observed in different SARS-CoV outbreaks (Hellewell et al. 2020; J. Wallinga 2004).

Initially, the European COVID-19 surveillance strategy was to monitor the incidence of the disease, its severity and viral modifications. After the initial phase, the surveillance system was improved, however, the initial goals were maintained and systematic improvements in testing policies were implemented. A factor of growing concern is the Variants of Concern (VOC), which need to be quickly understood so that resources can be applied to the related emergencies. Finally, the current context with the availability of vaccines, brings a general change in the epidemiology of COVID-19, also demanding strategies to monitor its effectiveness, as well as the implementation of programs to guarantee the necessary distribution, strategy and coverage (Centre for Disease Prevention 2021).

There are many approaches in terms of surveillance of COVID-19, routine, active, syndromic, sentinel, sentinel-syndromic, laboratory, hospital and others that can provide more accurate parameters for the control of the virus. However, there are also numerous challenges, mainly related to costs, human resource capacity, underreporting of cases and lack of time between the occurrence and registration of cases (Ibrahim 2020). At the beginning of the epidemic, for example, the diagnosis of COVID-19 was one of the most critical problems, due to the limited availability of laboratory supplies for performing the RT-PCR, considered the most gold standard for

the diagnosis of SARS-CoV-2 infection. Initially, the epidemiological approach was essential, and the clinical manifestations of COVID-19 included respiratory symptoms such as fever, cough, dyspnea and other nonspecific symptoms, making the clinical approach more complex (Diaz-Quijano et al. 2020).

Surveillance systems, timely, sensitive, specific, and with easily interpretable results, are crucial in the response to PHE. In most countries, disease surveillance is passive, where records refer to patients who sought health facilities. These data are commonly biased due to the quality of access and significant delay. The timeliness of information is also largely affected by the magnitude of the health event, during high transmission seasons the already saturated health system can distort the true incidence of the disease (Bastos et al. 2019).

Surveillance data are essential to support the emergency response. Forecasting systems are especially useful when indicators used for decision making and subsequent intervention proposals are scarce, helping to improve the prevention and control of pathogens (Pei et al. 2021). It is especially problematic when there is still an absence of historical data that help characterize the magnitude of the event. The experience gained with COVID-19 should value the adoption of uncomplicated models that include health resource infrastructure and, whenever possible, sociodemographic and behavioral aspects, being scalable to the point of estimating the occurrence of simultaneous health events (Dembek, Chekol, and Wu 2018)

Parameters of the disease's natural history are indispensable in the construction of epidemiological intelligence that allow understanding the dispersion, magnitude and effectiveness of the intervention's through the epidemic control. These parameters consist of indicators that can be calculated or used in prediction models of cases and their outcomes, mainly generating evidence to support decision making. The Attack Rate, Incidence, prevalence, basic reproduction number (R_0); serial interval; incubation period; transmissibility period, proportion of detected cases; mortality, case fatality rate, are examples of indicators used to monitor the course and magnitude of epidemics. (Gallo et al. 2020).

Table 1. Description of the main epidemiological parameters from COVID-19.

Parameter	Description
Basic reproduction number (R0)	The average number of new infections generated by an infected person in a fully susceptible population.
Serial Interval	The time between the onset of disease in a primary (infective) case and the onset of disease in a secondary (infected) case.
incubation period	The time between infection and onset of disease.
communicability period	The time during which a person infected with SARS-CoV-2 transmits the virus to another person.
Proportion of detected cases	Proportion of cases identified as infected with SARS-CoV-2 among all cases tested.
Proportion of critical cases among hospitalized patients	Proportion of critical COVID-19 cases among all hospitalized cases.
Proportion of deaths among critical cases	Proportion of deaths from COVID-19 among all critical cases of the disease.
Proportion of deaths among critical cases	Time in days (average or median) of hospitalization between COVID-19 cases.
Mean or mean time between hospitalization and development of Severe Respiratory Syndrome	Time in days (average or median) of hospitalization among COVID-19 cases before the development of Severe Respiratory Syndrome.
Length of stay in the ward before admission to the ICU	Time in days (average or median) of hospitalization among COVID-19 cases that required ICU.

Source: (Gallo et al. 2020).

Using these parameters, researchers around the world have created models to plan and evaluate strategies for surveillance and control of the transmission of the SARS-CoV-2 virus, including vaccine strategy scenarios, pointing out better resource applications, and risk scenarios for the occurrence of new waves and overloading of health systems (Sonabend et al. 2021; Dembek, Chekol, and Wu 2018). European governments have used several mathematical models to simulate scenarios that support decision-making on COVID-19, the estimates obtained by these models, can be used as a guide policy, providing accurate results on scenario estimation (Ainslie et al. 2022; Shen et al. 2021)

Characteristics of COVID-19 among pediatric populations

The decision of governments to close schools, day care centers and universities in response to the pandemic came in part because it had been previously demonstrated during the influenza pandemic as an effective preventive public health measure. In this scenario, it was thought that children were among the main spreaders of the virus and that, keeping them at home, it was possible to significantly minimize the

emergence of new cases (Esposito et al., 2021; Viner et al., 2021) since there was also evidence that, after the reopening of schools, the number of contacts per case increased in all age groups (Ingelbeen et al. 2021; Macartney et al. 2020).

This intervention model was further discussed because of the balance between the risk of transmission and the fact that the closure of schools could cause social, economic and health problems, for example, nutritional aspects of children that depend on the meals offered in schools. The impacts of this measure can this beyond the educational field, also affecting social, economic aspects, beyond the emotional costs for children and young people considering the interruptions in other areas of activity of schools, such as nutrition, mental health and safety and social assistance services (Esposito, Cotugno, and Principi 2021; Keeling et al. 2021; Kriemler et al. 2021; Lo Moro et al. 2020; López-Bueno et al. 2021).

It is necessary to gather evidence that demonstrates the impact on the variation of SARS-CoV-2 infections associated with the closure of schools, especially in conjunction with other public health measures implemented in the territory. The result of this evaluation may suggest and evidence how general health measures may have impacted the school scenario itself and the risk of transmission of SARS-CoV-2 from child to child and to education professionals, in addition to providing information on how and what health protocols can allow the occurrence of school activities without substantial impact on morbidity and mortality (Esposito, Cotugno, and Principi 2021; Kriemler et al. 2021).

Monitoring the COVID-19 scenario in a school environment, with studies that allow the description of outbreaks, risk factors, associated exposures, transmission dynamics and health protocols adopted, such as contact screening, case and suspect isolation, and vaccine strategy, can provide evidence on the impact of school closures as a pandemic control measure that are relevant for disease control and decision making (Lo Moro et al. 2020; Viner et al. 2021; Zhang et al. 2020).

Data on SARS-CoV-2 occurrence in children are scarce due to low testing at the beginning of the pandemic (Manivannan et al. 2021) and parameters and evidence about COVID-19 occurrence in adult can't always be extrapolate to children (Escosa-García et al. 2020).

Estimates based on home secondary attack rates influenced by symptomatic surveillance, estimate that young adults under 35 years of age have the highest prevalence (Goldstein, Lipsitch, and Cevik 2021; Keeling et al. 2021), although, according to contact tracing the secondary attack rate was similar in children and adults (Bi et al. 2020; Zhang et al. 2020). Since the beginning of the pandemic, the contribution of children in the virus spread has been discussed (Bi et al. 2020). Screening of asymptomatic patients and diagnostic issues makes this problem more complex, however, in fact, it is known that children are not the main source of spread of the virus and therefore interventions based on this public can have an impact below expected (Soriano-Arandes et al. 2021; Lugon et al. 2021). According to evidences, children are not major drivers of transmission (Bubar et al. 2021).

Although a high proportion of asymptomatic infection concentrates the role of adolescents and young people in the dispersion of COVID-19 draws attention due to the similarities between viral load and transmission to adults meanwhile, there seems to be consensus that children contribute less to the infection. A Belgian study found that the number of contacts was higher in the age group of 10 to 19 years (Ingelbeen et al. 2021).

A meta-analysis concluded that young children are less susceptible to SARS-CoV-2, with a ratio of 0.56 compared to adults. Another study showed that susceptibility to infection increased with age, people from 0 to 14 years had a lower risk of infection compared to 15 to 64 years (OR = 0.34 95% CI: 0.24 to 0.49 and $p < 0.0001$). Among those infected, the elderly had more severe outcomes, including higher mortality rates (Bi et al. 2020; Viner et al. 2021; Zhang et al. 2020).

Contact tracing studies found no typical or frequent child-adult transmission (Lugon et al. 2021; Yi et al. 2021; Zimmerman et al. 2021) and a low contribution of children in the secondary cases (Ertem et al. 2021; Park et al. 2020), which showed that children do not seem to be the main source of infection (Ismail et al. 2021; Escosa-García et al. 2020). Also, modeling studies already been demonstrated an increased risk for infection in household contacts patterns that were a risk factor, consistent with in this study and previous studies that demonstrated an increased risk of infection associated with household contacts (Soriano-Arandes et al. 2021; Pollán et al. 2020; Marks et al. 2021; Kim et al. 2020; Munday et al. 2021). In this study, contact at school had a negative association with the infection by SARS-CoV-2, reinforcing that well-

implemented sanitary protocols make a safe school reopening possible. Studies using contact screening data have shown that the attack rate was similar in children and adults, but in children aged 0 to 4 to 9 years, they were less than half, when compared to the group aged 15 to 19 years, suggesting that children under 10 years of age are susceptible to infection by adults, however an infection rate of 7.4% in children < 10 years versus 6.6% in the general population suggested that children were as likely to be infected as adult.

A literature review with a series of PCR-based studies of SARS-CoV-2 infection shows how similar the results are: OR for infection in <18 years versus adults 0.18 (95% CI, 0.06 - 0.54), aged 4-18 versus 19-60 years 0.09 (95% CI, 0.01 to 0.73); multivariate OR for infection <15 versus 15–64 years 0.34 (95% CI, 0.24–.49) multivariate OR to <15 years versus 15-64 was 0.58 (95% CI, 0,34 - 0,98) and OR <18 years in versus 18–29 years of 0.41 (95% CI, 0.17– 0.99) (Bi et al. 2020; Goldstein, Lipsitch, and Cevik 2021; Keeling et al. 2021; Viner et al. 2021; Zhang et al. 2020).

Retrospective epidemiological surveillance data in the pediatric population made available by different countries are difficult to interpret due to the fact that the widespread closure of schools to limit the spread of the virus probably influenced a lower infection and transmission than in the adult population, however, with the reopening of schools, the role of children in the transmission of the SARS-CoV-2 infection is beginning to be characterized, the associated factors and the likely prevention and control measures in the school environment.

There is also a concern that teachers and school staff may have high exposure, given that children have high levels of contact, therefore suggesting that preventive measures should be put in place as a precaution. Many institutions, including Public Health Agencies and Education Departments, have indicated the need to monitor COVID-19 in the school environment and evaluate the long-term implementation of infection prevention and control measures.

Impact and acceptability of COVID-19 vaccine

As a pharmacological intervention, the European Medicines Agency (EMA) authorized several vaccines against SARS-CoV-2. On December 21, 2020, was

authorized the first vaccine against COVID-19, the Comirnaty Pfizer-BioNTec for people over 18 years. On December 27, 2020, the vaccination started in Spain prioritizing specific and vulnerable groups such health care workers (HCW), school staff, and people with underlying diseases and older (España, Ministerio de Sanidad, and Grupo de trabajo técnico de vacunación COVID-19 2021).

The protection attributed and the population-level benefit makes the COVID-19 vaccine fundamental to change the impact of the pandemic (Watson et al. 2022). Although vaccine seems the best solution to control the COVID-19, earlier modelling studies was suggested that vaccinate alone was insufficient to contain the outbreak (Moore et al. 2021; Nguyen et al. 2021), especially in scenarios with vaccine-resistant strains (Rella et al. 2021). By the other side, countries with slower vaccination that maintain zero-COVID strategy to stop the transmission had the risk of increasing rates of SARS-CoV-2 infections (Watson et al. 2022).

The actual phase with decline of mortality and hospitalization reflects the vaccination strategy, since evidence showed that vaccination can promote an important control on burden and mortality by infectious diseases (Voysey et al. 2021; Steinert et al. 2022; Olusanya et al. 2021). Prioritizing vaccination among individuals over 60 years can reduce hospitalizations and deaths and prioritized younger adults (20-40 years) can reduce symptomatic infections (Foy et al. 2021). However, data about household transmission show that this transmission model was about 40-50% lower among vaccinated index patients (Harris et al. 2021).

In comparison with adults, infected children usually show mild symptoms, but since the changes in the epidemiological situation and approval of vaccines for children under 18 years of age, the focus of the vaccine strategy has been moving towards this public in order to guarantee not only individual protection but as a strategy for collective protection (Du, Chen, and Shi 2022), Children's vaccination is recommended due to effects including neuropsychological impairment, impact on social life and to ensure safely open for schools, especially if were evidences that the closure of schools can bring negative effects on children reducing access to essential social, nutritional and healthcare supports (Ceannt et al. 2022; Cupertino et al. 2022), also, to reach high vaccination rates against COVID-19 (Rees et al. 2022).

Despite the evidenced of vaccination for COVID-19 cost-benefit by preventing severe cases and deaths, hesitation and vaccine refusal is still a concern. Equitably vaccine distribution, improve on infrastructure and strategies against misinformation and vaccine refuse could be improve the vaccine demand (Watson et al. 2022).

Vaccine hesitance is defined as a delay in acceptance or refusal despite the vaccine availability, and, according WHO, is a major treats to public health (Byrne et al. 2022; Ceannt et al. 2022).

Normally, concerns about side effects are the main reason for hesitation of childhood vaccinations, however, the unprecedented speed of the development and production of the COVID-19 vaccine, and doubts about long-term safety, technology, immunity durability, brough uncertainty among parents been often cited as reason to hesitancy, moreover, studies are demonstrating increase in vaccine hesitance compared to the early phases of the pandemic (Byrne et al. 2022). Low intentions of vaccination can be predicted (Dubé, Gagnon, and Pelletier 2022). Understand barriers and facilitator of vaccine uptake and under vaccination improve the reginal capacity to deal with the issues around vaccine delivery, coordination of strategies and formulation of guidelines, especially aimed at populations with greater refusal or greater vulnerability (Crawshaw et al. 2022).

Factor associated with vaccine hesitance are multicomplex, including parental age, educational level, income, concerns about safety, low trust, inadequate information, risk perception, perceived susceptibility and perceived benefits of the vaccine (Dao et al. 2023; Kyei-Arthur et al. 2022; Liu et al. 2022; Qin et al. 2022), while have their parents vaccinated work as a good predictor for youngers acceptance showing that parents decision affect the adolescents immunization, also, the role of pediatricians and school educators in increased vaccine coverage among adolescents is quite clear (Cupertino et al. 2022).

PURPOSE

Generate evidence to improve strategies for surveillance, prevention and control of SARS-CoV-2 transmission among students of Catalonia, Spain.

RESEARCH QUESTIONS

1. What is the magnitude of SARS-CoV-2 infection among students in Catalonia?
2. What characteristics influence SARS-CoV-2 transmission among students?
3. How can we improve detection of SARS-CoV-2 infections among students?
4. How are students' conducts towards SARS-CoV-2 prevention?
5. Why adolescents and parents refuse the COVID-19 vaccine?
6. How is students' emotional wellbeing affected by COVID-19 pandemic?
7. Which reasons are related to school absences?

SPECIFIC OBJECTIVES

1. To assess the occurrence of SARS-CoV-2 infections among students at Sentinels Schools of Catalonia.
2. To identify the potential determinants of SARS-CoV-2 infections.
3. To determine the feasibility of a by-monthly SARS-CoV-2 testing strategy.
4. To describe students' knowledges, attitudes and behaviors toward to prevent and control of SARS-CoV-2.
5. To identify determinants of COVID-19 vaccine hesitation and refusal among students over 16 years and parents of students under 16 years.
6. To describe the impacts of the COVID-19 on the mental health of students over 15 years.
7. To identify clinical and epidemiological parameters associated to health-related school absences among primary school population.

OPERATIONAL OBJECTIVES:

Research question 1: How many students were infected with the SARS-Cov-2 virus in Catalonia?

Specific objective: To assess the occurrence of SARS-CoV-2 infections among students at Sentinels Schools of Catalonia.

Operational objective: To calculate the prevalence and incidence of SARS-CoV-2 exposures and infections through students' biological using antibody and antigen tests.

Research question 2: What characteristics influence SARS-CoV-2 transmission among students?

Specific objective: To identify the potential determinants of SARS-CoV-2 infections.

Operational objective: To collect students' information to test and describe the association between sociodemographic and epidemiological characteristics and SARS-CoV-2 infections among students at Sentinels Schools of Catalonia.

Research question 3: How can we improve detection of SARS-CoV-2 infections among students?

Specific objectives: To determine the feasibility of a by-monthly SARS-CoV-2 testing strategy.

Operational objectives: To implement a by-monthly SARS-CoV-2 testing strategy and to develop a model to calculate the minimum necessary number of tests to find one SARS-CoV-2 infection among symptomatic and asymptomatic students.

Research question 4: How are students' conducts towards SARS-CoV-2 prevention?

Specific objective: To describe students' knowledges, attitudes and behaviors toward to prevent and control of SARS-CoV-2.

Operational objectives: To develop a survey and to analyze the data to achieve a global comprehension about prevention and control measures to minimize the spread and infection of the SARS-CoV-2 virus among students.

Research question 5: Why adolescents and parents refuse the COVID-19 vaccine?

Specific objectives: To identify determinants of COVID-19 vaccine hesitation and refusal among students over 16 years and parents of students under 16 years.

Operational objectives: To collect information about vaccine acceptability among students over 16 years and parents of students under 16 years. To apply a machine learning model to assess the factors related to COVID-19 vaccine hesitation and refusal.

Research question 6: How is students' emotional wellbeing affected by COVID-19 pandemic?

Specific objective: To describe the impact of the COVID-19 on the mental health of students over 15 years.

Operational objectives: To apply validated epidemiological instruments to achieve information about the impacts caused by COVID-19 over students' mental health.

Research question 7: Which reasons are related to school absences?

Specific objectives: To identify clinical and epidemiological parameters associated to health-related school absences among primary school population.

Operational objectives: To adapt a syndromic surveillance instrument to identify symptoms among children at primary school. To apply a latent class model to assess the correlation between respiratory syndromes and school absence.

Table 2. Correspondence between the research questions, specific and operational objectives and the publications included in the doctoral thesis.

RESEARCH QUESTIONS	SPECIFIC OBJECTIVE	OPERATIONAL OBJECTIVE	RELATED PUBLICATIONS
How many students were infected with the SARS-Cov-2 virus in Catalonia?	To assess the occurrence of SARS-CoV-2 infections among students at Sentinels Schools of Catalonia.	To calculate the incidence and prevalence of SARS-CoV-2 exposures and infections through students' biological using antibody and antigen tests.	Ganem, Fabiana, Anna Bordas, Cinta Folch, Lucia Alonso, Marcos Montoro-Fernandez, Andreu Colom-Cadena, Ariadna Mas, et al. 2022. "The COVID-19 Sentinel Schools Network of Catalonia (CSSNC) Project: Associated Factors to Prevalence and Incidence of SARS-CoV-2 Infection in Educational Settings during the 2020–2021 Academic Year." PLOS ONE 17 (11): e0277764. https://doi.org/10.1371/journal.pone.0277764 . (Ganem et al. 2022)
What characteristics influence SARS-CoV-2 transmission among students?	To identify the potential determinants of SARS-CoV-2 infections.	To collect students' information to test and describe the association between sociodemographic and epidemiological characteristics and SARS-CoV-2 infections among students at Sentinels Schools of Catalonia.	Ganem, Fabiana, Anna Bordas, Cinta Folch, Lucia Alonso, Marcos Montoro-Fernandez, Andreu Colom-Cadena, Ariadna Mas, et al. 2022. "The COVID-19 Sentinel Schools Network of Catalonia (CSSNC) Project: Associated Factors to Prevalence and Incidence of SARS-CoV-2 Infection in Educational Settings during the 2020–2021 Academic Year." PLOS ONE 17 (11): e0277764. https://doi.org/10.1371/journal.pone.0277764 . (Ganem et al. 2022)
How can we improve detection of SARS-CoV-2 infections among students?	To determine the feasibility of a by-monthly SARS-CoV-2 testing strategy.	To develop a model to calculate the minimum necessary number of tests to find one SARS-CoV-2 infection among symptomatic and asymptomatic students.	Ganem, Fabiana, Anna Bordas, Cinta Folch, Lucia Alonso, Marcos Montoro-Fernandez, Andreu Colom-Cadena, Ariadna Mas, et al. 2022. "The COVID-19 Sentinel Schools Network of Catalonia (CSSNC) Project: Associated Factors to Prevalence and Incidence of SARS-CoV-2 Infection in Educational Settings during the 2020–2021 Academic Year." PLOS ONE 17 (11): e0277764. https://doi.org/10.1371/journal.pone.0277764 . (Ganem et al. 2022)
How are students' conducts towards SARS-CoV-2 prevention?	To describe students' knowledges, attitudes and behaviors toward to prevent and control of SARS-CoV-2.	To develop a survey and to analyze the data to achieve a global comprehension about prevention and control measures to minimize the spread and infection of the SARS-CoV-2 virus among students.	Ganem, Fabiana, Anna Bordas, Cinta Folch, Lucia Alonso, Marcos Montoro-Fernandez, Andreu Colom-Cadena, Ariadna Mas, et al. 2022. "The COVID-19 Sentinel Schools Network of Catalonia (CSSNC) Project: Associated Factors to Prevalence and Incidence of SARS-CoV-2 Infection in Educational Settings during the 2020–2021 Academic Year." PLOS ONE 17 (11): e0277764. https://doi.org/10.1371/journal.pone.0277764 . (Ganem et al. 2022)
Why adolescents and parents refuse the COVID-19 vaccine?	To identify determinants of COVID-19 vaccine hesitation and refusal among students	To collect information about vaccine acceptability among students over 16 years and parents of students under 16 years. To	Ganem, Fabiana, Cinta Folch, Andreu Colom-Cadena, Anna Bordas, Lucia Alonso, Antoni Soriano-Arandes, Jordi Casabona, and on behalf of Sentinel School Network Study Group of Catalonia. 2023.

	over 16 years and parents of students under 16 years.	apply a machine learning model to assess the factors related to COVID-19 vaccine hesitation and refusal.	“Determinants of COVID-19 Vaccine Hesitancy among Students and Parents in Sentinel Schools Network of Catalonia, Spain.” Edited by Harapan Harapan. PLOS ONE 18 (3): e0282871. https://doi.org/10.1371/journal.pone.0282871 . (Ganem, Folch, et al. 2023)
How is students’ emotional wellbeing affected by COVID-19 pandemic?	To describe the impacts of the COVID-19 on the mental health of students over 15 years.	To apply validated epidemiological instruments to achieve information about the impacts caused by COVID-19 over students’ mental health.	Folch C, Ganem F, Colom-Cadena A, Martínez I, Cabezas C, Casabona J, on behalf of COVID-19 Sentinel School Network Study Group of Catalonia. Impact of the COVID-19 pandemic on the psychological well-being of adolescents by gender identity. (Folch et al 2023)
Which reasons are related to school absences?	To identify clinical and epidemiological parameters associated to health-related school absences among primary school population.	To adapt a syndromic surveillance instrument to identify symptoms among children at primary school. To apply a latent class model to assess the correlation between respiratory syndromes and school absence.	<u>Additional article</u> - Ganem, Fabiana, Lucia Alonso, Andreu Colom-Cadena, Anna Bordas, Cinta Folch, Antoni Soriano-Arandes, and Jordi Casabona. 2023. “Syndromic Surveillance as a Predictive Tool for Health-Related School Absences in COVID-19 Sentinel Schools in Catalonia, Spain.” Preprint. Epidemiology. https://doi.org/10.1101/2023.03.24.23287681 . (Ganem, Alonso, et al. 2023)

METHODOLOGY

Study context

The Sentinel School project (in Català Escoles Sentinella) was conceived and implemented by the Center for Epidemiological Studies on Sexually Transmitted Infections and AIDS of Catalonia (CEEISCAT), which acts as coordinator, the Global Health Institute of Barcelona (ISGlobal), Hospital Universitari Vall d'Hebrón and IrsiCaixa's Living Laboratory of Health and funded by the Department of Health and the Catalan Institute of Health (ICS), in coordination with the Department of Education.

The aims of the CSSNC project include the monitoring of biological markers; knowledge, attitudes and behaviors towards SARS-CoV-2 preventive measures; the identification of both facilitators and barriers to their implementation; and the monitoring of environmental indicators such as CO₂, all together through a participatory research approach. The study protocol was previously published (Bordas et al. 2022).

The main objective of the project was to describe knowledge, attitude and behavior (KAB) towards COVID-19 among students, non-teaching staff (PND) and teachers, as well as describe the impact of established measures and interventions to prevent the transmission of SARS-CoV-2 in the environment school over time, describe the determinants, barriers and needs regarding the use of measures to prevent the transmission of SARS-CoV-2 in the school environment, estimate the occurrence and monitor the dynamics of infection by SARS-CoV-2 and its determinants in the school environment and identify and implement specific interventions through participatory research and ad hoc sub-studies.

Study design

This is a cross-sectional multicenter study to understand the sociodemographic, behavioral, structural and environmental factors associated with SARS-CoV-2 infection and to evaluate the interventions that are being adopted to adapt them and be able to improve prevention and treatment. control of new cases.

The study is divided into work packages that use different methodologies to achieve their proposed objectives:

A. Bioconductual research

Serial cross-sectional study with semi-annual data collection methodology on knowledge, attitudes and behaviors in relation to SARS-CoV-2 infection, impact of COVID-19 on mental health and acceptability of vaccination. It was carried out through individual surveys addressed to students, teaching and non-teaching staff (PND), available online through the REDCap platform, or on paper if the participants requested it. Surveys were distributed at the beginning (October-November) and at the end of the course (May-June). In total, three survey models were created: survey of teaching and non-teaching staff (Survey A), survey of students under 16 years old (Survey B) answered by parents or legal guardians and survey of students over 16 years old of age (Survey C), answered by the students themselves. Surveys were available in Catalan, Spanish and English. Regarding the knowledge of acceptability, doubts or rejection surrounding vaccination against COVID-19, information was also collected with an additional survey during the period from January to February, motivated by the appearance of new variants and approval of vaccination in children from of the 5 years in the previous weeks.

B. SARS-CoV-2 infection

Study to determine the presence of the SARS-CoV-2 virus in a nasal exudate sample using the TMA (transcription-mediated amplification) technique and the presence of anti-SARS-CoV-2 antibodies using rapid tests to detect active infection and seroprevalence, respectively. Samples are collected at the beginning (October to November 2021) and at the end of the course (May to June 2022). To complete the vaccination study, an additional antibody determination was performed during the month of January. The collection of biological samples is carried out only in 7 schools of the Sentinel Schools Network.

C. Participatory research

The study focused on solving community challenges involving schools, scientists and families as co-investigators. This study was implemented in collaboration with the project funded by the European Commission CONNECT, within the framework of the Open Schooling movement promoted by the European Commission. Students are actively involved in participatory research processes to solve local problems following three steps: Care-Know-Do. Two versions of activity guides were designed following these methodological frameworks: a short one (6 hours in the classroom) and a long one (12 hours in the classroom) so that teachers can decide on the time to dedicate.

The methodology is structured in the following phases: I) Preparatory phase to involve the Sentinel Schools; II) Consultation phase (I) with virtual workshops with teachers, management teams and mental health professionals in the form of participatory focus groups to analyze the problems and opportunities of the current model of mental health promotion in educational centers and develop recommendations for improvement; III) Phase of presentation and exploration of the project with students and families IV) Consultation phase (II) with focus groups with students and interviews with families carried out by students; V) Phase of integration and analysis of the results obtained and elaboration of a preliminary list of recommendations from IrsiCaixa's Living Health Lab; VI) Phase of validation of the list of recommendations by the educational community; VII) Evaluation phase with surveys to assess the impact of participatory research on knowledge, skills and attitudes towards science. VIII) Phase of dissemination of results to the educational and scientific community and institutions. IX) Phase of programming and implementation of the recommendations.

D. Impact of COVID-19 on emotional well-being

Exploratory qualitative methodology to assess the impact of COVID-19 on the emotional well-being of young people attending school in Catalonia through semi-structured anonymous and face-to-face interviews in participating educational centers from March to June 2022, and carried out with adolescents aged 12 to 18 years old, parents and teachers from different socio-cultural contexts within the Sentinel Schools. Participants are selected following a convenience sampling technique, and the interview script includes a description of past and current mental health status, self-perception of the impact of COVID-19 on mental health, emotional management of the pandemic, and barriers and facilitators to promotion mental health in times of pandemic. Questions to parents and teachers focus on their perception of the mental health status of young people, thus contrasting the information collected by young people. The final sample size was determined by the principle of data saturation (when the data obtained are redundant). Data from the qualitative mental health study were analyzed following the thematic analysis method proposed by Braun and Clarke¹⁰ The results were presented to a group of experts for verification and/or modification.

E. Environmental and Structural Assessment of Educational Centers

Study of the factors that can influence the transmissibility of the virus through: I) structural characterization of the educational center by a field technician who selects at least one classroom per year from each school, including the number of 'students/m² in the register and

m³, type, number and surface of windows, and surface and volumes of classrooms, among others; II) installation of a carbon dioxide (CO₂) sensor during two periods of the school year (October-January and March-June) in 8 classrooms of each center previously selected together with the management of the center, to measure weekly the CO₂ values, temperature and humidity of the classrooms while collecting information on the number of hours in class, students, teachers and ventilation practices; III) online surveys (EU survey platform) addressed to directors of centers on heating and ventilation systems in schools; IV) surveys directed at tutors in the sampled classes on ventilation measures and other prevention factors against COVID-19; V) installation of passive diffusion tubes during the months of March and June on the façades of the schools and in the classrooms where the CO₂ sensors were also located, to measure the levels of nitrogen dioxide (NO₂) and thus also assess the pollution atmospheric. KKmoon and Dioxcare CO₂ devices are used to measure CO₂, temperature and humidity, and passive diffusion tubes to collect data on nitrogen dioxide (NO₂) levels.

F. Ventila't i queda't (Ventilate and stay): Effect of ventilation on absenteeism and respiratory infections.

Observational case-control study to assess the effect of ventilation on absenteeism and transmission of the SARS-CoV-2 coronavirus and other respiratory viruses in kindergarten and primary school classrooms selected on the basis of average CO₂ level (high ≥ 700 ppm, medium between ≤ 500 and > 700 ppm, or low < 500 ppm) previously measured during the 2020-21 and 2021-22 school years 2 early childhood classrooms are selected as the control group given the low level of CO₂ previously determined in all, and 9 primary schools with low (n=3), medium (n=3) and high (n=3) levels of CO₂. Interventions carried out between April and June 2022 were: i) continuous CO₂ measurements; ii) collection of epidemiological, clinical and diagnostic data from absent students to determine the percentage of absenteeism and whether the causes are related to respiratory infections; iii) analysis of the direct relationship or not of the percentage of school absences with the levels of CO₂ inside the classroom; iv) correlation analysis of CO₂ levels in the classrooms with the period of time (days) of school absence at the individual level and of the total stable living group (GCE); v) quantification of secondary attack rate and presence of epidemic outbreaks (5 or more cases) of SARS-CoV-2 and/or other respiratory viral infections in classrooms chosen based on CO₂ levels.

G. Avui com et trobes? (How are you today?) Acceptability and feasibility of syndromic surveillance

Longitudinal descriptive study to assess the acceptability and feasibility of syndromic surveillance in schools carried out in 6 elementary school classes (students aged 6 to 11 years and tutors) from 3 educational centers participating in the project, between May and June 2022. Students respond to a brief daily anonymous survey on paper for four weeks with questions about health status and the onset and severity of respiratory symptoms; and the teachers, in addition to distributing and collecting these surveys, respond weekly to a questionnaire, also on paper, where the number of absences per day is recorded and classified according to health reasons of respiratory or other origin. In the last week, the tutor also answers another questionnaire about the acceptability of the intervention. Data are entered by the research team through the REDCap platform.

H. Persistence of masks in classrooms: Reasons and circumstances for maintaining mask use

Cross-sectional study, carried out between April and May 2022. Les Escoles Sentinella faculty inform the research team how many people wear masks in the classroom and how many do not, classified by course, group and date. In this way, a percentage of people wearing a mask is obtained according to the school year. A qualitative study was also carried out to deepen the perception of young people in educational centers about the persistence of the use of masks once their obligation was suspended in indoor spaces. Semi-structured interviews were carried out with young people aged between 12 and 17 years old in three sentinel schools, with the aim of understanding the reasons and circumstances in which some of them continued to wear the mask.

Study population

The project was based in Sentinel Schools platform, defined as a network of schools representing the organizational, structural and epidemiological diversity of the schools and the scholar population in Catalonia territory, to project useful educational and health policies regarding the prevention and control of SARS-CoV-2 infection.

The project including 23 sentinel schools and 4,533 children and adolescents and 1,158 staff from all over Catalonia. Participants were selected following a convenience sampling technique, so that participation was voluntary with prior signing of a free and informed consent form.

Data Collection

The collection of information was carried out quarterly during the academic years 2020-2023. Students, teaching and non-teaching staff (PND) of the Sentinel Schools (N=50) answered surveys on knowledge, attitudes and behavior (KAB) and epidemiology. Surveys for students under age 16 have been contested by parents or guardians. Two field teams collected various biological samples to detect anti-SARS-CoV-2 antibodies and/or the presence of the virus. Structural and environmental information was collected from the centers during visits by field researchers.

Capillary blood samples were collected for rapid antibody testing, non-invasive nasal swab samples were collected for rapid antigen testing, RT-PCR and viral co-infections, and saliva and nasal swab samples were collected to validate the use of the sample in 5 Sentinel Schools for RT testing. -PCR and rapid antigen test. Capillary blood and one of the nasal samples were processed at the time of extraction to perform the rapid antibody test and rapid antigen test. At this time, the nursing team performed a first reading of the test and attached a photo of the result of each test and, using a tablet, to the study database. A nasal sample was sent to the microbiology laboratory of the Hospital Universit rio Vall d'Hebr n to carry out RT-PCR and sequencing of the SARS-CoV-2 virus in these samples from patients with active infection, to study the evolutionary dynamics of the viruses in time and time. space as well as to investigate co-infections with other viruses.

All samples with a positive result, once processed, were frozen at -80 C and stored in the Biobank of the German University Hospital Trias i Pujol (Biobank IGTP-HUGTP) during the project period. Once the project is completed, these samples will be incorporated into the sample collections of the participating laboratories in the case of the HUVH, in accordance with Article 22 of Royal Decree RD 1716/2011. Saliva and nasal exudate samples sent to the microbiology laboratory of the University Hospital Germans Trias i Pujol negative in the molecular study of SARS-CoV-2 or in the study of the presence of antigens were kept in the sample file of the Microbiology Service of the LCMN during a week.

Indicators, variables and information sources

The variables to be collected in the KAB surveys are mainly based on the WHO proposal: WHO/Europe (2020). Monitoring knowledge, risk perceptions, preventive behaviors and public confidence in the current coronavirus outbreak - standard WHO protocol.

1. Generals. Survey date, school, type of questionnaire (adult, child <16 years, child >16 years).
 - i. Sociodemographic: Gender, age, sex, country of birth, level of education, population of residence, occupation, economic situation, information regarding the environment where you live (number of people living together/number of rooms or similar, people over 65 years old at home, m² of the home).
 - ii. COVID-19 infection: confirmed COVID-19 infection, presentation of symptoms since the start of the pandemic, onset of symptoms, type of symptoms, hospitalization, use of COVID-19-related treatments, close contact with positive cases, number and degree of exposure
 - iii. Clinic and health status: current state of perceived general and mental health, pathologies and medications.
 - iv. Knowledge, attitudes and conduct: Knowledge about COVID-19 symptoms, transmission routes, prevention measures, higher-risk groups, risk perception, attitudes towards infection, treatments and vaccines, use of preventive measures inside and outside school (greeting during confinement, washing hands, distancing in social interactions, avoiding contact with elderly people, etc.).
 - v. Impact of the COVID-19 pandemic. Changes in socioeconomic, work and psychosocial health status (self-perceived health status)
 - vi. Vaccine acceptability
 - vii. School-related information: levels of education covered in the school, number of students, teaching and non-teaching staff, timetables for each class and assigned class, information on the protocol and list of measures taken to avoid transmission.
 - viii. Environmental and structural variables (inspection during school visits): number of classrooms, number of desks/classroom, number of students/m², m² of school and classrooms, m² of patios/area outdoor area, common areas, classroom ventilation, etc.

Secondary sources of information:

- a. AQUAS, SISAP-IDIAP individual variables: PCR tests or serologies performed:
- b. AQUAS, SISAP-IDIAP Ecological variables: number of new confirmed or positive cases of SARS-CoV-2 COVID-19 by PCR/total residents, number of new confirmed or positive cases of SARS-CoV-2 COVID-19 by PCR/ total number of people tested and

number of new COVID-19 cases confirmed or positive for SARS-CoV-2 by PCR/Number of suspected cases.

- c. AQUAS, SISAP-IDIAP Socioeconomic variables by Basic Health Areas (ABS) where each of the schools is located based on the report by the AQUAS Catalonia Health Inequalities Observatory

Data Analysis

A descriptive analysis was performed to identify and characterize possible population groups at higher risk of SARS-CoV-2 infection, investigation of factors associated with SARS-CoV-2 infection, as well as preventive measures implemented in the school environment that may have a positive impact using univariate and multivariate logistic regression models. The seroprevalence obtained and the 95% confidence interval were calculated, as well as the seroprevalence by age, sex and basic health area (ABS). Interventions were evaluated by comparing the seroconversion and disease rates of different groups (pre- and post-intervention) and considering the time series of the population in the corresponding ABS.

Ethics statement

All these studies listed here were approved on 17 December 2020 by the Ethical Committee of the Foundation University Institute for Research in Primary Health Care Jordi Gol I Gurina (IDIAPJGol) (code 20/192-PCV). A written informed consent was obtained from school staff, and since it includes minors, was signed for parents or guardians of children under 16 years and by participants older than 16 years that signed by themselves. All documents were archived in a place accessed only by the researchers. The signed document provided information about, procedures, risks, use of the collected data, anonymity, confidentiality, and general information about the study. All participants were free to decline/withdraw consent at any time without providing a reason and without being subject to any resulting detriment.

RESULTS

ARTICLE 1

The COVID-19 Sentinel Schools Network of Catalonia (CSSNC) Project: associated factors to prevalence and incidence of SARS-CoV-2 infection in educational settings during the 2020-2021 academic year.

SUMMARY

Objective of the study: to estimate the prevalence and incidence of SARSCoV-2 exposure and infections and to identify potential associated factors associated to them, among students and staff of the CSSNC during the academic year 2020–2021. Moreover, as a secondary objective, feasibility of a monthly testing strategy is also assessed.

Study design: were used two methodological approaches: a cross-sectional study to estimate SARS-CoV-2 prevalence, and a longitudinal study to calculate the COVID-19 incidence and evaluate the feasibility of the twice-monthly testing strategy. The cross-sectional component was performed between February 22 and March 22, 2021, and the longitudinal component, were proceeded through 4 data collection rounds, between 6–19 April 2021, 20 April 2021 and 03 May 2021, 04 May 2021 and 18 May 2021 being the last round between 19 May 2021 and 02 June 2021.

Study population: In this study, were included 2,007 students and 520 school staff (personal) who previously signed the informed consent, from seven schools all over Catalonia. Although they are an opportunistic sample, epidemiological, and sociodemographic characteristics of the area, as well as type of school (public, private or chartered) were considered to assure heterogeneity. The cross-sectional component included students aged 3–19 from preschool (3–5 years old), elementary school (7–10-year-old), middle school (12–15-year-old), high school (16–17 year-old) and vocational training (17–19 year-old) and school staff. For the longitudinal component, were included in a cohort of 1,424 participants, 983 students over 12 years-old and 441 school staff.

Data collection: We collected nominal data from an online questionnaire that included questions about demographic and economic characteristics, health status, knowledge, perceptions and behaviors related to COVID-19, control measures, pandemic impacts, previous SARS-CoV-2 infection, symptoms and contacts pattern as health indicators. Secondary data were provided by the Agència de Qualitat i Avaluació Sanitàries de Catalunya (AQuAS) through the Primary Care Services Information System (SISAP) and Data Analytics Program for Health Research and Innovation (PADRIS), which collect programmatic data from different sources. Biological samples were collected from all participants to perform a rapid serological anti-SARS-CoV-2 IgM/IgG test to estimate the initial and final seroprevalence in February and

June 2021 respectively. Saliva and nasal swab were collected twice a month to investigate the presence of SARS-CoV-2 RNA and SARS-CoV-2 antigens.

Variables, outcome and case definitions: Factors that could have impact in outcome were referred to as independent variables. They were categorized in sociodemographic, health status, contact patterns, knowledge and perceptions and, preventive measures. Our first outcome was previous exposure to SARS-CoV-2 virus. The case definition for positive, was any individual with a positive SARS-CoV-2 IgG. The second outcome was active SARS-CoV-2 infections, we consider as positive any individual, symptomatic or asymptomatic with a positive RT-PCR or RAT performed by the project team or by primary health care, during the follow-up period.

Data analysis: Univariate analysis was performed to investigate the association between independent variables and outcome, variables with p-value <0.050 were considered statistically significant. The prevalence ratio with 95% confidence interval (CI) were calculated using an adjusted Poisson model with robust error and adjustment for age, sex and school. The combined qualitative variables were compared using the McNemar test. For the multivariate analysis, we performed a stepforward and stepwise regression We used the same type of regression as for univariate models (GLM Poisson with robust errors). To calculate the incidence rate for the at-risk population, we used the number of participants with a positive result in RT-PCR or RAT divided by person time at risk. For at risk of infection we excluded individuals with RT-PCR or RAT positive result in the previous 60 days before started the cohort. The denominator was defined as the sum of the time at risk of the 1,366 participants sampled during the the longitudinal component, a univariate analysis was performed included the same variables that had been tested in the cross-sectional component, adding the information collected during the follow-up endpoints. These data were assessed using independent log binomial mixed models to calculate the Relative Risk (RR). For the univariate analysis, a GLMM log binomial model with ID as random intercept was used to estimate the PR and RR of each variable of interest, by means of an adjusted measure and avoiding the confusion of the variables age, sex and school.

Results: The baseline seroprevalence of SARS-CoV-2 IgG for students and school staff was, respectively, 14.8% (95% CI: 13.1–16.5) and 22% (95% CI: 18.3–25.8); adjusted for sensitivity and specificity it was 15.2% (95% CI: 13.5–17) and 22.6% (95% CI: 19–26.7) and the weighted seroprevalence was 14.5% (95% CI: 12–17.1) and 22.0% (95% CI: 21.2–22.8).

The seroprevalence of SARS-CoV-2 IgG at the end of the longitudinal component for students over 12 years-old and staff was 18.4% (95% CI: 15.6–21.1) and 42.6% (95% CI: 37.7–47.5), adjusted for sensitivity and specificity it was 18.9% (95% CI: 16.2–21.9) and 43.8% (95% CI: 38.8–49.0) and the weighted seroprevalence was 19.7% (95% CI: 13.3–26.1) and 42.5% (95% CI: 0–92.4).

The prevalence of active SARS-CoV-2 infection confirmed by RT-PCR or RAT at baseline was 0.7% (95% CI: 0.3–1.0) in students and 1.1% (95% CI: 0.1–2.0) in school staff. Weighted prevalence was 1% (95% CI: 0–2.1) and 1.1% (95% CI: 1–1.1). Self-reported documented infection of SARS-CoV-2 between February 2020 and March 2021 was 8.5% (95% CI: 7.3–9.8) for students and 7.1% (95% CI: 4.9–9.3) for staff. For students, when weighted by sex and age it was 8.2% (95% CI: 4.3–12.2) and for staff when weighted by sex it was 7.1% (95% CI: 5.9–8.4).

Among those participants who had two serological tests at baseline and at the end of the longitudinal component (round four), there was a significant increase in prevalence ($p < 0.001$). The main differences were in the staff group (p -value < 0.001), although there was also a no significant increase among students in vocational studies. The variables included in the univariate analysis, for students and staff were presented into sociodemographic, health and behaviors and contact patterns categories. Indiscriminate changes in the employment situation (PR 1.43, CI 1.07–1.91) and improved the economic situation (PR 2.66 CI 1.18–6.00) regarding parents and school staff were positively associated with having been infected. The variable higher perceived knowledge was positively associated with the infection (PR 1.68 CI 1.05–2.68). The public health measure, avoiding crowded spaces was negatively associated with the infection (PR 0.65 CI 0.45–0.93) and a higher risk perception was positively associated (PR 1.49 CI 1.14–1.93). Having unspecific contact with suspected or confirmed COVID-19 case, (PR 2.76; CI 1.94–3.93) or contact at home (PR 2.17; CI 1.62–2.91) were positively associated with the infection, in contrast, contact at school, had a strongly negative association (PR 0.60 CI 0.45–0.80). Living with a health professional was not associated with infection (p -value = 0.262).

In the multivariate analysis, the same significance and trend among socioeconomic, health measures and contact patterns variables were observed. Incidence and univariate analysis at the longitudinal component during the longitudinal component of the study, 45 new infections occurred (34 students and 11 staff), 11 of them identified by RT-PCR performed by the project

team and 34 self-reported in by the participants. It is interesting to note that out of 11 RT-PCR positives identified in the study, only 1(9%) was also detected by RAT. The overall incidence was 2.73 (95% CI 1.991, 3.653) per 100 person-month, that is 2.887 (95% CI 1.999, 4.034) and 2.337 (95% CI 1.167, 4.182) per 100 person-month for students and staff, respectively.

The variables included in the univariate analysis were also categorized into sociodemographic and socioeconomic indicators, health status, and preventive compliance. There was a protective behavior associated with socioeconomic status, when comparing the highest level (high) in reference to the first tercile (low) (RR 0.25, 95% CI 0.06–0.96) for the COVID-19 infection. Contact with a suspected or confirmed case of COVID-19, was a risk factor for infection (RR 6.44, 95% CI 3.15–13.19). When the contact occurred at home, the risk (RR 12.42, 95% CI 5.81–26.52) was higher than compared to school (RR 3.73, 95% CI 1.49–9.38) and other nonspecific locations (RR 5.28, 95% CI 2.1–13.27).

We tested several sanitary measures that had been carried out in the last seven days before the survey and only avoiding close contact with someone who is infected or at risk (RR 0.38, 95% CI 0.15–0.97) and a wearing mask (RR 0.14, 95% CI 0.04–0.53) were associated, this is compatible with the also significant result of the variable contact with suspected or confirmed cases of COVID-19. We tested the feasibility of a twice a month RT-PCR testing strategy. Considering a prevalence of 0.07% and accuracy of 0.05) 1,258 participants should be tested to find one positive.

The COVID-19 Sentinel Schools Network of Catalonia (CSSNC) Project: associated factors to prevalence and incidence of SARS-CoV-2 infection in educational settings during the 2020-2021 academic year.

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Abstract

The Sentinel Schools project was designed to monitor and evaluate the epidemiology of COVID-19 in Catalonia, gathering evidence for health and education policies to inform the development of health protocols and public health interventions to control of SARS-CoV-2 infection in schools. The aim of this study was to estimate the prevalence and incidence of SARS-CoV-2 infections and to identify their determinants among students and staff during February to June in the academic year 2020-2021. We performed two complementary studies, a cross-sectional and a longitudinal component, using a questionnaire to collect nominal data and testing for SARS-CoV-2 detection. We describe the results and perform a univariate and multivariate analysis. The initial crude seroprevalence was 14.8% (95% CI: 13.1-16.5) and 22% (95% CI: 18.3-25.8) for students and staff respectively, and the active infection prevalence was 0.7% (95% CI: 0.3-1) and 1.1% (95% CI: 0.1-2). The overall incidence for persons at risk was 2.73 per 100 person-month and 2.89 and 2.34 per 100 person-month for students and staff, respectively. Socioeconomic, self-reported knowledge, risk perceptions and contact pattern

variables were positively associated with the outcome while sanitary measure compliance was negatively associated, the same significance trend was observed in multivariate analysis. In the longitudinal component, epidemiological close contact with SARS-CoV-2 infection was a risk factor for SARS-CoV-2 infection while the highest socioeconomic status level was protective as was compliance with sanitary measures. The small number of active cases detected in these schools suggests a low transmission among children in school and the efficacy of public health measures implemented, at least in the epidemiological scenario of the study period. The major contribution of this study was to provide results and evidence that help analyze the transmission dynamic of SARS-CoV-2 and evaluate the associations between sanitary protocols implemented, and measures to avoid SARS-CoV-2 spread in schools.

Keywords: COVID-19, SARS-CoV-2, school closure, longitudinal studies

Introduction

The Coronavirus Disease 19 (COVID-19) outbreak began in Wuhan, China in December 2019 and rapidly became an international public health emergency. As of March 2022, there had been more than 470 million cases and 6 million deaths globally [1]. The first case of COVID-19 in Spain was confirmed on January 31, 2020, and in Catalonia on February 25 [2]. Until March 2022, the Catalan region had registered more than 2 million accumulated cases and more than 26,000 deaths [3].

At the beginning of the pandemic, in March 2020, it was estimated that 107 countries and 862 million children and young people were affected by the closure of schools, one of the public health measures aiming to reduce the transmission of SARS-CoV-2 [4]. However, this number increased to 1.57 billion students worldwide over the following months [5]. Many governments chose to close schools in response to the pandemic because it has previously been shown to be an effective non-pharmacological prevention measure in the control of other virus spread like influenza [4,6] where children have had a significantly contribution [7–9]. Nevertheless, at the beginning of the current pandemic, data on the prevalence of COVID-19 in children was scarce due to low testing of the pediatric population [10] and the fact that parameters and evidence about COVID-19 occurrence in adults could not be extrapolated to children [11]. A great deal of effort was made to resolve this question.

Since the beginning of the pandemic, the contribution of children in the virus spread has been discussed [12]. People aged from 0 to 14 had a lower risk of SARS-CoV-2 infection

compared to those of 15 to 64, additionally, among the infected, older people had more severe outcomes and reported higher mortality rates [4]

Despite estimates based in household secondary attack rates may be influenced due to several factors such as contact patterns, increased exposure, and symptomatic surveillance, which depends on the sensitivity of case detection, even several serological studies estimate highest prevalence among adults under 35 years [13,14], it is known that children are not the main source of spread of the SARS-CoV-2 virus and therefore interventions based on this public can have an impact below expected [15,16].

The impact of school closure could also cause social, economic and health problems, with emotional costs for children and young people considering the interruptions to other areas of activity in schools such as, nutrition, mental health, safety, and social assistance services [6,13,14,17–19].

In Catalonia (7,739,758 inhabitants) the closure of the 5,492 schools on 13 March 2020 affected 1,582,478 students and 116,999 teaching staff. The schools were reopened on 14 September 2020, immediately after the school vacations, between June and August, remaining closed, therefore, for six months [20].

The current schools' guidelines were developed by the Government of Catalonia based on SARS-CoV-2 indicators. They include early detection and isolation as well implementation of public health measures as natural ventilation of classrooms, stable coexistence groups (SCG or bubble groups) and targeted screening [21,22], also monitoring COVID-19 risk factors, determinants, transmission dynamics, preventive measures compliance and outbreaks in the school to provide evidence to improve the safety of schools preventing further closures and their impact [4,18,23].

The COVID-19 Sentinel Schools Network of Catalonia (CSSNC) is a part of the COVID-19 monitoring and evaluation plan from the Health Department of Catalonia. The main objective is to monitor and evaluate the epidemiological situation of COVID-19 and its determinants in the educational setting, to gather evidence for the health policies aimed at the prevention and control of SARS-CoV-2 infection in schools and as a platform for other applied research projects. Currently, in 2022, the CSSNC includes 23 schools with 4,221 children and 1,140 staff from all over Catalonia, the study protocol has been previously published [24].

The aims of the CSSNC project (www.escolessentinella.org) include: the monitoring of biological markers; knowledge, attitudes and behaviors towards SARS-CoV-2 preventive measures; the identification of both facilitators and barriers to their implementation; and the monitoring of environmental indicators such as CO₂, all together using a participatory research approach [24].

In this paper, to answer the question about the occurrence of COVID-19 among school-aged population, the main objectives are to estimate the prevalence and incidence of SARS-CoV-2 exposure and infections and to identify potential associated factors associated to them, among students and staff of the CSSNC during the academic year 2020-2021. Moreover, as a secondary objective, feasibility of a by-monthly testing strategy is also assessed.

Materials and methods

Study design and population

In this study, were included 2,007 students and 520 school staff (teaching and non-teaching staff, such as extracurricular education instructors and administrative personal) who previously signed the informed consent, from seven schools all over Catalonia. Although they are an opportunistic sample, epidemiological, and sociodemographic characteristics of the area, as well as type of school (public, private or chartered) were considered to assure heterogeneity. During the study period, we used two methodological approaches: a cross-sectional study to estimate SARS-CoV-2 prevalence, and a longitudinal study to calculate the COVID-19 incidence and evaluate the feasibility of the twice-monthly testing strategy.

The cross-sectional component included students aged 3-19 from preschool (3-5 year-old), elementary school (7-10 year-old), middle school (12-15 year-old), high school (16-17 year-old) and vocational training (17-19 year-old) and school staff.

For the longitudinal component, were included in a cohort of 1,424 participants, 983 students over 12 years-old and 441 school staff.

Data collection

The cross-sectional component was performed between February 22 and March 22, 2021, and the longitudinal component, were proceeded through 4 data collection rounds,

between 6-19 April 2021, 20 April 2021 and 03 May 2021, 04 May 2021 and 18 May 2021 being the last round between 19 May 2021 and 02 June 2021 (Fig 1).

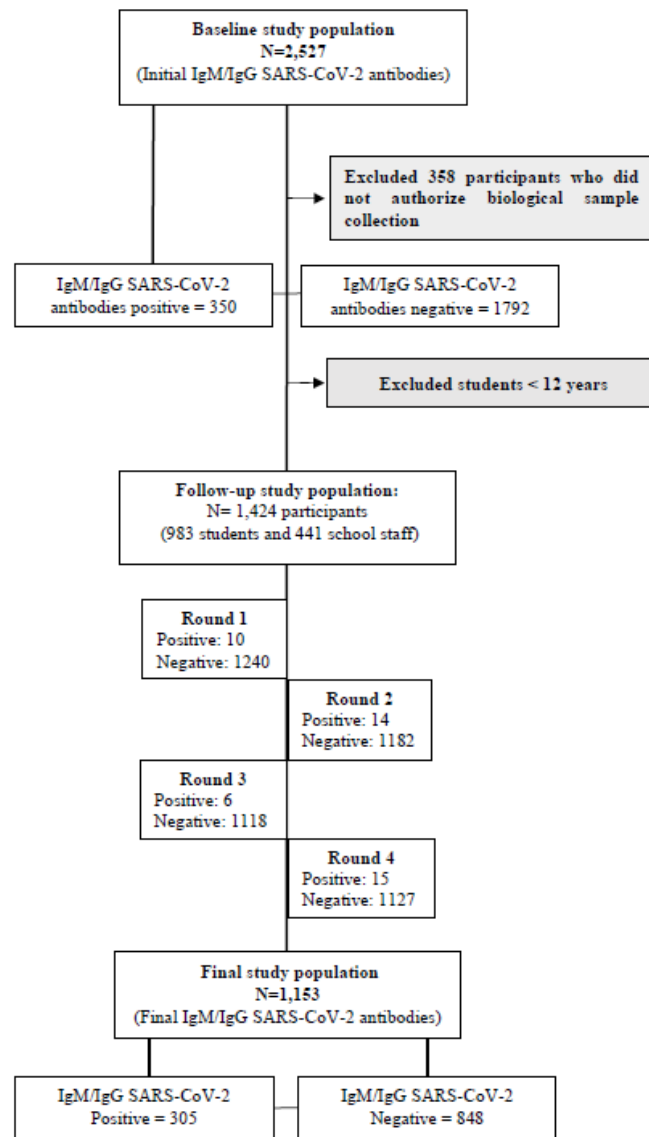


Fig 1. Flowchart of population at cross-sectional and longitudinal prospective components of the study.

We collected nominal data from an online questionnaire but, when necessary, a paper form was used. Questions about demographic and economic characteristics, health status, knowledge, perceptions and behaviors related to COVID-19, control measures, pandemic

impacts, previous SARS-CoV-2 infection, symptoms and contacts pattern as health indicators were included according to COSMO questionnaire [25]. In each longitudinal round, participants filled in an additional online epidemiological survey with information related to SARS-CoV-2 infection, suspected symptoms, exposures, and vaccine status during the previous 15 days.

Three different questionnaire models were designed one for school staff (questionnaire A); one for students under 16 years, which were answered by parents/guardian (questionnaire B) and one for students over 16 years (questionnaire C).

Secondary data about vaccine coverage and socioeconomic level was provided by the Agència de Qualitat i Avaluació Sanitàries de Catalunya (AQuAS) through the Primary Care Services Information System (SISAP) and Data Analytics Program for Health Research and Innovation (PADRIS), which collect programmatic data from different sources. The variable socioeconomic level was based on the sanitary regions and was used to categorize the place of residences in tertiles (high, medium and low).

Biological samples were collected from all participants. A finger prick blood was collected to perform a rapid serological anti-SARS-CoV-2 IgM/IgG test to estimate the initial and final seroprevalence in February and June 2021 respectively. Saliva and nasal swab were collected twice a month to investigate the presence of SARS-CoV-2 RNA and SARS-CoV-2 antigens.

All results were uploaded to the electronic health record, and, become available to the participants normally within 48 hours of the sample collection.

Independent variables

Factors that could have impact in outcome were referred to as independent variables, that were tested to investigate the association with the SARS-CoV-2 infection. They were categorized in sociodemographic, health status, contact patterns, knowledge and perceptions and, preventive measures. Each variable was coded according to the type of the question asked in the questionnaire (Table 1).

Table 1. Independent variables included in the study, CSSNC Catalonia, Spain 2021.

Sociodemographic	
Sex	Male / Female
Age	Years [IQR]
Parents' occupation	Dichotomized: Employed / unemployed, retired and lay-of
Parents' or school staff level of completed studies	Higher studies or university / Secondary school / Primary school or None
House size (in meters)	Dichotomized: >70m ² / <70m ²
Economic situation	Changed to worse / improved
Socioeconomical status	Low / middle / high
Parents or Staff changed employment status during the pandemic	yes / no
Contact pattern	
Contact with suspected or confirmed COVID-19 cases (Unspecific)	yes / no
Place of contact with suspected or confirmed COVID-19 cases	Home / school / other
Living with a healthcare professional	yes / no
Main mode of transport	On foot / bicycle / own motorcycle or car / public transport / school bus
Avoiding contact in crowded spaces	Likert 5-point scale dichotomized: No (never, almost never or sometimes) Yes (most of the time or always)
Health Status	
Self-reported health status	Likert 7-point scale dichotomized: Low (1-4) / High (5-7)
Underlying medical conditions	yes / no
Specific underlying medical conditions	Hypertension / Asthma / Obesity / Diabetes mellitus / Chronic heart disease
Knowledge and perceptions	
Perceived knowledge	Likert 5-point scale dichotomized: No (never, almost never or sometimes) Yes (most of the time or always)
Perception of risk	Likert 7-point scale dichotomized: Low (1-4) / High (5-7)
Compliance of preventive measures in the last 7 days	
Washing hands	yes / no
Avoiding close contact with someone who is infected or at risk	yes / no
Avoiding crowded spaces or crowds	yes / no
Avoiding closed or indoor spaces	yes / no
Ventilating closed spaces whenever possible	yes / no
Wearing a mask	yes / no
Self-isolation	yes / no
Frequently disinfecting used objects	yes / no
Avoiding public transportation	yes / no
Use of hand sanitizing gels	yes / no
Avoiding touching the face, eyes, mouth with unwashed hands	yes / no
Staying at home if I have a cold or other illness	yes / no
Avoiding trips abroad	yes / no
Covering the mouth with the elbow when coughing or sneezing	yes / no

Laboratory assays

A RT-PCR assay (Allplex SARS-CoV-2/FluA/FluB/RSV, Werfen, Korea) and a molecular assay based on the transcription mediated amplification assay (TMA) (Procleix SARS-CoV-2, Grifols, Barcelona, Catalonia, Spain) was conducted to detect SARS-CoV-2 RNA. The nasal swab samples for detection of SARS-CoV-2 antigen were processed using the Panbio COVID-19 Ag Rapid Test (Abbot, Chicago, IL, USA), following the manufacturer's instructions, with a sensitivity of 93.3% (95% CI: 83.8-98.2%) and specificity of 99.4% (95% CI: 97.0-100%). For the anti-SARS-CoV-2 IgM/IgG test we used a rapid SARS-CoV-2 serological test (COVID-19 IgG/IgM Rapid Test Kit, Lambra, Madrid, Spain), following the manufacturer's instructions, with sensitivities of 97.2% (IgG) and 87.9% (IgM),

and specificities of 100% for both immunoglobulins, but following recommendations to the Public Health Protocol for COVID-19 [22], because of the low specificity of IgM antibodies and several reported cross-reactions with other non-specific proteins, only IgG antibodies were used to assess the prevalence of SARS-CoV-2.

The samples that SARS-CoV-2 were detected were stored in the sample collection C.0001145 located at the Vall d'Hebron Hospital Universitari (Barcelona, Spain) in the sample collection registered at the Instituto de Salud Carlos III register, Madrid, Spain. Saliva samples with positive SARS-CoV-2 results were frozen and stored at the IGTP-HUGTiP Biobank, Badalona, Catalonia, Spain, and maintained for two years.

Outcomes and case definitions

Our first outcome was previous exposure to SARS-CoV-2 virus. The case definition for positive, was any individual with a positive SARS-CoV-2 IgG antibodies detected by rapid test.

The second outcome was active SARS-CoV-2 infections. The case definition for positive was any individual, symptomatic or asymptomatic with a positive RT-PCR or RAT detected by the project team or detected and confirmed by RT-PCR or RAT performed by primary health care, during the follow-up period. We decided to include these self-reported documented infections because students and school staff with positive results started the isolation protocol and were no longer tested at school.

Data analysis

We calculated crude and adjusted prevalence for students of 2-20 years of age on the census in Catalan schools, adjusting for age and sex. For school staff, we only adjusted for sex and then by sensitivity and specificity of the tests. The differences between initial and final seroprevalence were only calculated for students from first grade of middle school or older and staff, using the McNemar test.

Descriptive analysis was performed, and the data were provided globally and stratified by educational stage when possible and presented considering sociodemographic and socioeconomic indicators; contact pattern; knowledge, behavior and perceptions of COVID-19 and health status. Frequency, measures of central tendency (mean and median) and dispersion (standard deviation and IQR) were calculated.

Univariate analysis was performed to investigate the association between independent variables and outcome, variables with p-value <0.050 were considered statistically significant. The prevalence ratio with 95% confidence interval (CI) were calculated using an adjusted Poisson model with robust error and adjustment for age, sex and school. The combined qualitative variables were compared using the McNemar test.

For the multivariate analysis, we proceeded an initial correlation graph (polychoric correlation) was constructed for each category of variables and of the pairs that had a correlation coefficient greater than 0.8 (in absolute value), only one of the variables was used for the analysis. To fit a multivariate model, we performed the analysis with stepforward and stepwise regression, ie. starting with the model with all variables, then removing them one by one and subsequently starting with an empty model adding the variables one by one. We used the same type of regression as for univariate models (GLM Poisson with robust errors). We selected variables by significance, R2 and AIC, and both models (stepforward and stepwise regression) gave us the same model with R2 0.184547 and AIC 1261.318, compatible with the set of behavioral variables included in the model. We checked the Goodness of fit for the multivariate model and observed that no overdispersion was found in the Poisson model.

To calculate the incidence rate for the at-risk population, we used the number of participants with a positive result in RT-PCR or RAT divided by person time at risk. For at risk of infection we excluded individuals with RT-PCR or RAT positive result in the previous 60 days before started the cohort. The denominator was defined as the sum of the time at risk of the 1,366 participants sampled during the cohort (950 students and 416 employees). Time at risk was defined for each participant, as the difference of time between the moment that they entered the study and the endpoint when they tested positive or, if they did not obtain any positive result, the last round that they were tested. The result was presented *per 100 person-month*.

In the longitudinal component, a univariate analysis was performed included the same variables that had been tested in the cross-sectional component, adding the information collected during the follow-up endpoints. These data were assessed using independent log binomial mixed models to calculate the Relative Risk (RR) with participant's identifier as random effect and adjusting for age, sex and school. Due the low number of positives, a multivariate model for the longitudinal component was not proceed.

For the univariate analysis, a GLMM log binomial model with ID as random intercept was used to estimate the PR and RR of each variable of interest, by means of an adjusted measure and avoiding the confusion of the variables age, sex and school.

Two composite indicators were created to measure the participant's knowledge of COVID-19: “*perceived knowledge*” and “*factual knowledge*” and another indicator to measure the “*risk perception*”. The “*perceived knowledge*” and “*risk perception*” were measured using a Likert 7-point scale, 1-4 scores were considered as *low* level of knowledge or *low* level of risk perception and 5-7 as *high* level. And “*factual knowledge*” was measured by a binary score composed of three aspects: people at risk, symptoms and means of transmission. The answers were counted, and we classified as *high* level of *factual knowledge* when more than 50% of answers were correct and 50% or less as *low*.

All analyses were carried out with R (version 4.1.0). Confidence intervals for incidence were obtained using the ‘epi.conf’ function from ‘epiR’ package. The number of samples that should be tested to find a positive was calculated using Ene 3.0.

Ethics Statement

The Foundation University Institute for Research in Primary Health Care Jordi Gol i Gurina (IDIAPJGol) approved the study on 17 December 2020 (code 20/192-PCV). Informed consent was obtained from school staff, parents for those children under 16 and alumni aged 16 or older. Participants were free to decline/withdraw consent at any time without providing a reason and without being subject to any resulting detriment.

Results

For participants students, except for the preschool, most participants were female (55%) overall. Regarding socioeconomic variables, 821 (41.7%) students' fathers and 1,043 mothers (52.3%) have high levels of study or university qualifications, 1,705 (86.7%) of the students' fathers and 1613 (81.0%) of the students' mothers were employed in the study period (Table 2).

Table 2. General characteristics of the students participating in the Sentinel School project, Catalonia, Spain. February-March 2021.

Variables	Preschool N=223		Elementary school N=752		Middle school N=599		High school N=316		Vocational Training N=117	
	n	%	n	%	n	%	n	%	n	%
Sociodemographic and socioeconomic indicators										
Sex										
Female	108	48.4%	387	51.5%	306	51.1%	211	66.8%	92	78.6%
Male	115	51.6%	365	48.5%	293	48.9%	105	33.2%	25	21.4%
Age (years)	4.00 [3.00;5.00]		9.00 [7.00;10.0]		13.0 [12.0;15.0]		17.0 [16.0;17.0]		18.0 [17.0;19.0]	
Level of completed studies (father)										
Without formal education or incomplete primary Education	10	4.6%	36	5.00%	22	3.7%	4	1.3%	14	12.00%
Primary school certificate	38	17.4%	140	19.2%	135	22.9%	44	13.9%	40	34.2%
Secondary school certificate	63	28.8%	208	28.6%	159	26.9%	93	29.4%	33	28.2%
Higher studies or University	105	47.9%	329	45.2%	224	38.00%	154	48.7%	9	7.7%
Don't know	0	0.0%	2	0.3%	33	5.6%	18	5.7%	16	13.7%
Not applicable	3	1.4%	13	1.8%	17	2.9%	3	1.00%	5	4.3%
Level of completed studies (mother)										
Without formal education or incomplete primary Education	11	5.0%	43	5.8%	27	4.6%	4	1.3%	12	10.3%
Primary school certificate	22	10.0%	76	10.2%	91	15.3%	28	8.9%	40	34.2%
Secondary school certificate	42	19.1%	193	25.8%	168	28.3%	88	27.8%	34	29.1%
Higher studies or University	144	65.5%	427	57.2%	275	46.4%	182	57.6%	15	12.8%
Don't know	0	0.0%	4	0.5%	26	4.4%	12	3.8%	14	12.00%
Not applicable	1	0.5%	4	0.5%	6	1.00%	2	0.6%	2	1.7%
Occupation (father)										
Not applicable	8	3.7%	27	3.7%	39	6.6%	7	2.2%	12	10.3%
Others	2	0.9%	17	2.3%	8	1.4%	1	0.3%	3	2.6%
Retired	0	0.0%	5	0.7%	10	1.7%	7	2.2%	8	6.8%
Household keeper	2	0.9%	1	0.1%	0	0.0%	0	0.0%	0	0.0%
Unemployed	5	2.3%	17	2.3%	38	6.5%	9	2.9%	4	3.4%
Sick leave	3	1.4%	7	1.0%	9	1.5%	6	1.9%	6	5.1%
Employed	198	90.8%	652	89.8%	485	82.3%	286	90.5%	84	71.8%
Occupation (mother)										

Not applicable	5	2.3%	33	4.4%	23	3.9%	7	2.2%	3	2.6%
Others	4	1.8%	12	1.6%	8	1.4%	1	0.3%	3	2.6%
Retired	1	0.5%	0	0.0%	4	0.7%	1	0.3%	2	1.7%
Household keeper	19	8.7%	42	5.6%	56	9.4%	15	4.8%	14	12.0%
Unemployed	11	5.1%	29	3.9%	37	6.2%	6	1.9%	7	6.0%
Sick leave	3	1.4%	12	1.6%	7	1.2%	5	1.6%	8	6.8%
Employed	175	80.3%	618	82.8%	459	77.3%	281	88.9%	80	68.4%
House size (m2)										
<50 m2	1	0.5%	8	1.1%	12	2.0%	4	1.3%	0	0.0%
51-70 m2	22	10.0%	61	8.1%	57	9.6%	13	4.1%	10	8.6%
71-90 m2	85	38.5%	235	31.4%	131	22.0%	70	22.2%	28	23.9%
91-110 m2	48	21.7%	190	25.4%	132	22.2%	67	21.2%	17	14.5%
111-130 m2	35	15.8%	111	14.8%	93	15.6%	54	17.1%	15	12.8%
>130 m2	28	12.7%	142	19.0%	135	22.7%	76	24.1%	19	16.2%
Don't know	2	0.9%	4	0.5%	36	6.1%	49	15.5%	34	29.1%
Underlying medical conditions										
No	205	93.2%	698	93.4%	538	90.1%	289	91.5%	97	82.9%
Yes	15	6.8%	49	6.6%	59	9.9%	27	8.5%	20	17.1%
Specific underlying medical conditions (n=274)										
Hypertension	0	0.0%	0	0.0%	0	0.0%	1	3.7%	0	0.0%
Asthma	5	33.3%	12	25.5%	31	52.5%	8	29.6%	9	45.0%
Obesity	0	0.0%	0	0.0%	1	1.7%	0	0.0%	0	0.0%
Diabetes mellitus	0	0.0%	1	2.1%	3	5.1%	1	3.7%	1	5.0%
Chronic heart disease	2	13.3%	3	6.38%	1	1.7%	1	3.7%	0	0.0%

For school staff, mean [IQR] age was 43 [IQR 33-51], 410 (78.8%) were female, 418 (80.5%) had a high level of studies or university qualifications and 292 (56.2%) used their own car as the main means of transport. About 20% (104) had a comorbidity, the most common was asthma 23 (22.1%) and hypertension 21 (20.2%) (table 3)

Table 3. General characteristics of the school staff participating in the Sentinel School project, Catalonia, Spain. February-March 2021

Variables	School staff N=520	
	n	%
Sociodemographic and socioeconomic indicators		
Sex		
Female	410	78.8%
Male	110	21.2%
Age (years)	43.0 [33.0;51.0]	
Level of completed studies (school staff)		
Without formal education or incomplete primary Education	4	0.8%
Primary school certificate	28	5.4%
Secondary school certificate	69	13.3%
Higher studies or University	418	80.5%
House size (m2)		
<50 m2	15	2.9%
51-70 m2	71	13.7%
71-90 m2	143	27.5%
91-110 m2	112	21.5%
111-130 m2	72	13.8%
>130 m2	91	17.5%
Don't know	16	3.1%
Health status		
Underlying medical conditions		
No	416	80.0%
Yes	104	20.0%
Specific underlying medical conditions (n=274)		
Hypertension	21	20.2%
Asthma	23	22.1%
Obesity	8	7.7%
Diabetes mellitus	4	3.9%
Chronic heart disease	2	1.9%

Regarding epidemiological data for SARS-CoV-2 exposure risk, for students, the most common place of contact with suspected or confirmed case was at the school, being 65 (65.0%) in preschool group for school staff, 122 (63.2%) reported having contact with a suspected or confirmed case at the school (Table 4).

Table 4. Contact pattern of students and school staff participating in the Sentinel School project, Catalonia, Spain. February-March 2021.

Variables	Preschool		Elementary school		Middle school		High school		Vocational Training		School staff	
	N=223		N=752		N=599		N=316		N=117		N=520	
Lives with healthcare professional												
No	189	85.1%	656	87.6%	538	90.6%	274	86.7%	104	88.9%	442	92.9%
Yes	33	14.9%	93	12.4%	56	9.4%	42	13.3%	13	11.1%	34	7.1%
Main mode of transport												
On foot	152	68.2%	495	65.8%	378	63.3%	136	43.0%	22	18.8%	152	29.2%
Scooter/bicycle	30	13.5%	30	4.0%	29	4.9%	33	10.4%	1	0.9%	36	6.9%
Motorcycle/own car	81	36.3%	284	37.8%	173	29.0%	119	37.7%	71	60.7%	292	56.2%
Public transport	21	9.4%	89	11.8%	106	17.8%	103	32.6%	39	33.3%	97	18.7%
School bus	1	0.5%	5	0.7%	3	0.5%	1	0.3%	1	0.9%	0	0.0%
Contact with suspected or confirmed COVID-19 cases												
Don't know	72	32.6%	320	43.0%	155	26.1%	54	17.1%	22	18.8%	205	39.5%
No	48	21.7%	174	23.4%	168	28.2%	100	31.6%	24	20.5%	121	23.3%
Yes, with both confirmed and suspected cases	4	1.8%	22	3.0%	26	4.4%	23	7.3%	12	10.3%	40	7.7%
Yes, with suspected cases	5	2.3%	13	1.8%	16	2.7%	13	4.1%	4	3.4%	14	2.7%
Yes, with confirmed cases	92	41.6%	215	28.9%	230	38.7%	126	39.9%	55	47.0%	139	26.8%
Place of contact												
At home	42	42.0%	122	49.6%	115	42.3%	72	44.4%	23	32.4%	58	30.1%
At school	65	65.0%	137	55.7%	165	60.7%	82	50.6%	41	57.7%	122	63.2%
Leisure activities	2	2.0%	25	10.2%	53	19.5%	54	33.3%	17	23.9%	26	13.5%
Don't know	0	0.0%	3	1.2%	0	0.0%	8	4.9%	4	5.6%	0	0.0%
Others	5	5.0%	9	3.7%	17	6.3%	11	6.8%	16	22.5%	23	11.9%

Seroprevalence, univariate and multivariate analysis in the cross-sectional component

The baseline seroprevalence of SARS-CoV-2 IgG for students and school staff was, respectively, 14.8% (95% CI: 13.1 - 16.5) and 22% (95% CI: 18.3 - 25.8); adjusted for sensitivity and specificity it was 15.2% (95% CI: 13.5 - 17) and 22.6% (95% CI: 19 - 26.7) and the weighted seroprevalence was 14.5% (95% CI: 12 - 17.1) and 22.0% (95% CI: 21.2 - 22.8). The seroprevalence of SARS-CoV-2 IgG at the end of the longitudinal component for students over 12 years-old and staff was 18.4% (95% CI: 15.6 - 21.1) and 42.6% (95% CI: 37.7 - 47.5), adjusted for sensitivity and specificity it was 18.9% (95% CI: 16.2 - 21.9) and 43.8% (95% CI: 38.8 - 49.0) and the weighted seroprevalence was 19.7% (95% CI: 13.3 - 26.1) and 42.5% (95% CI: 0 - 92.4). The prevalence of active SARS-CoV-2 infection confirmed by RT-PCR or RAT at baseline was 0.7% (95% CI: 0.3 - 1.0) in students and 1.1% (95% CI: 0.1 - 2.0) in school staff. Weighted prevalence was 1% (95% CI: 0 - 2.1) and 1.1% (95% CI: 1 - 1.1). Self-reported documented infection of SARS-CoV-2 between February 2020 and March 2021 was 8.5% (95% CI: 7.3 - 9.8) for students and 7.1% (95% CI: 4.9 - 9.3) for staff. For students, when weighted by sex and age it was 8.2% (95% CI: 4.3 - 12.2) and for staff when weighted by sex it was 7.1% (95% CI: 5.9 - 8.4) (Table 5).

Table 5. Summary of crude and adjusted seroprevalence and active infections during the first trimester of 2021 in sentinel school project, Catalonia, Spain.

Indicator	Students n=2007 % (95%CI)	Staff n= 520 % (95%CI)
Seroprevalence		
Initial crude seroprevalence of SARS-CoV-2 IgG	14.8 (13.1 - 16.5)	22 (18.3 - 25.8)
Adjusted initial seroprevalence for sensitivity and specificity ¹	15.2 (13.5 - 17)	22.6 (19 - 26.7)
Weighted initial seroprevalence of SARS-CoV-2 IgG ²	14.5 (12 - 17.1)	22.0 (21.2 - 22.8)
Final crude seroprevalence of SARS-CoV-2 IgG (n=1153)	18.4 (15.6 - 21.1)	42.6 (37.7 - 47.5)
Adjusted final seroprevalence for sensitivity and specificity ¹ (n=1153)	18.9 (16.2 - 21.9)	43.8 (38.8 - 49.0)
Weighted final seroprevalence of SARS-CoV-2 IgG ² (n=1153)	19.7 (13.3 - 26.1)	42.5 (0 - 92.4)
Active infection		
Prevalence of active SARS-CoV-2 infection at baseline ³	0.7 (0.3 - 1.0)	1.1 (0.1 - 2.0)
Weighted prevalence of active SARS-CoV-2 infection at baseline ^{2,3}	1 (0 - 2.1)	1.1 (1 - 1.1)

1.COVID-19 IgG/IgM Rapid Test Kit, Lambra with sensitivities of 97,2% (IgG) and 87,9% (IgM), and specificities of 100%

2. Weighted according to 2020 student censused in Catalonia age 2-20 years by sex and age and school staff by sex. Estimated prevalence of the biological samples collected by the project team or the applied questionnaire

3. Biological samples collected during baseline, TMA with nasal swab performed by project team between Feb and Mar 2021

Abbreviations: IgG: immunoglobulin G; 95% CI: 95% Confidence interval

Among those participants who had two serological tests at baseline and at the end of the longitudinal component (round four), there was a significant increase in prevalence ($p < 0.001$). The main differences were in the staff group (p -value < 0.001), although there was also a no significant increase among students in vocational studies (Fig 2).

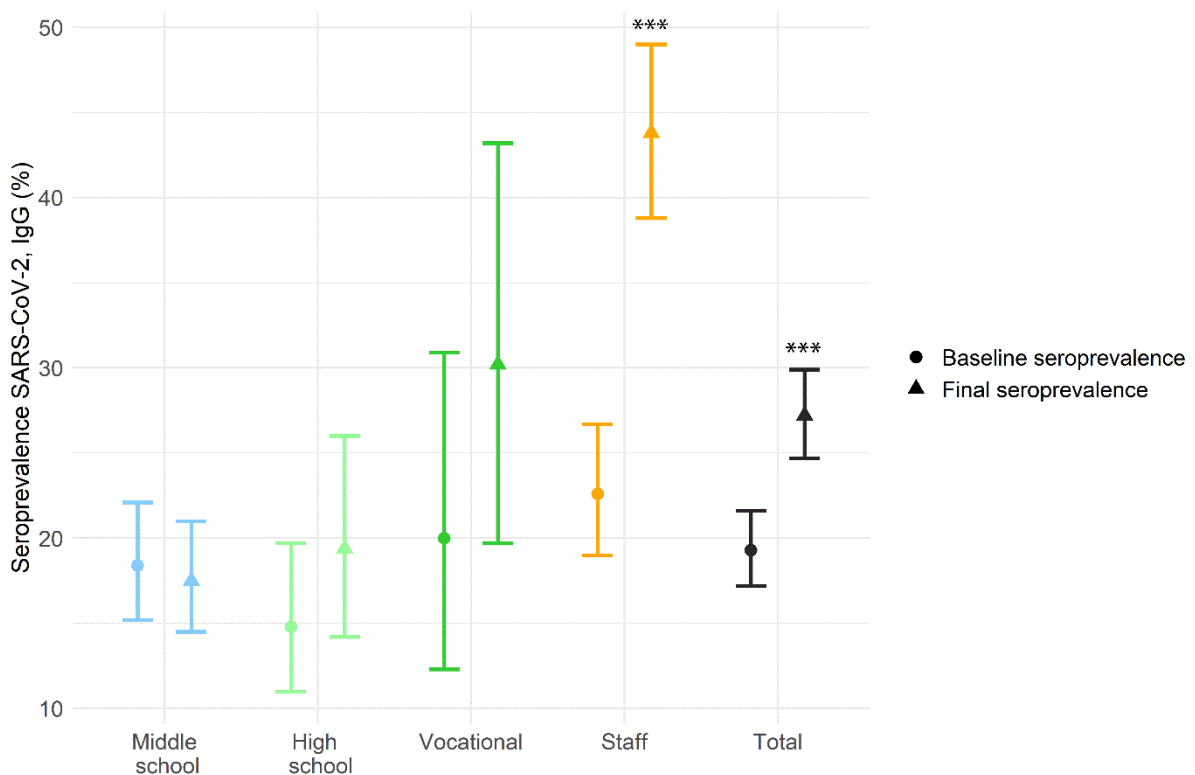


Fig 2. Adjusted seroprevalence of antibodies IgG anti-SARS-CoV-2 in longitudinal population by educational stages and school staff at the baseline (February-March 2021) and the last follow-up (May-June 2021). *** $p < 0.001$ using McNemar test.

The variables included in the univariate analysis, for students and staff were presented into sociodemographic, health and behaviors and contact patterns categories. Indiscriminate changes in the employment situation (PR 1.43, CI 1.07-1.91) and improved the economic situation (PR 2.66 CI 1.18-6.00) regarding parents and school staff were positively associated with having been infected. The variable higher perceived knowledge was positively associated

with the infection (PR 1.68 CI 1.05-2.68). The public health measure, *avoiding crowded spaces* was negatively associated with the infection (PR 0.65 CI 0.45-0.93) and a higher *risk perception* was positively associated (PR 1.49 CI 1.14-1.93) (Table 6)

In the case of contact patterns, *having unspecific contact with suspected or confirmed COVID-19 case*, (PR 2.76; CI 1.94-3.93) or contact at home (PR 2.17; CI 1.62-2.91) were positively associated with the infection, in contrast, contact at school, had a strongly negative association (PR 0.60 CI 0.45-0.80). *Living with a health professional* was not associated with infection (p-value= 0.262). (Table 7).

Table 6. Summary and univariate analysis between SARS-CoV-2 infection and sociodemographic, health and behavioral indicators of students and staff from sentinel schools. Catalonia, February to March 2021.

Variables	Students				Staff				Total				Univariate analysis		
	Positive N=180		Negative N=1827		Positive N=41		Negative N=479		Positive N=221		Negative N=2306		Prevalence ratio (PR)	p-value	
	n	%	n	%	n	%	n	%	n	%	n	%			
Sociodemographic															
Sex														-	-
Female	101	56.1	1003	54.9	32	78.0	378	78.9	133	60.2	1381	59.9	-	-	
Male	79	43.9	824	45.1	9	22.0	101	21.1	88	39.8	925	40.1	-	-	
Age (years)	15.0 [11.0;16.0]		12.0 [8.00;15.0]		45.0 [32.0;50.0]		43.0 [33.5;51.0]		15.0 [12.0;18.0]		13.0 [9.00;17.0]		-	-	
Changed employment status during the pandemic															
No	128	73.1	1418	79.7	34	82.9	392	82.7	162	75.0	1810	80.3	ref		
Yes	47	26.9	362	20.3	7	17.1	82	17.3	54	25.0	444	19.7	1.43 (1.07-1.91)	0.015	
Economic situation															
Changed to worse	40	88.9	407	96.4	3	60.0	69	82.1	43	86.0	476	94.1	ref		
Improved	5	11.1	15	3.6	2	40.0	15	17.9	7	14.0	30	5.9	2.66 (1.18-6.00)	0.019	
Socioeconomical status															
Low	77	42.8	837	46.5	23	56.1	239	51.1	100	45.2	1076	47.4	ref		
Middle	43	23.9	542	30.1	13	31.7	132	28.2	56	25.3	674	29.7	0.74 (0.52-1.06)	0.098	
High	60	33.3	422	23.4	5	12.2	97	20.7	65	29.4	519	22.9	1.12 (0.76-1.65)	0.582	
Knowledge and perceptions															
Perceived knowledge **															
Low	13	24.1	150	37.8	7	17.1	135	28.2	20	21.1	285	32.5	ref		
High	41	75.9	247	62.2	34	82.9	344	71.8	75	78.9	591	67.5	1.68 (1.05-2.68)	0.030	
Risk perception**															
Low	120	66.7	1435	79.2	17	41.5	228	47.6	137	62.0	1663	72.6	ref		
High	60	33.3	377	20.8	24	58.5	251	52.4	84	38.0	628	27.4	1.49 (1.14-1.93)	0.003	

* Likert scale. No: never, almost never or sometimes; Yes: most of the time or always

** Likert scale. Low: 1-4; High: 5-7

*** GLM adjusted Poisson model with robust error and adjustment for age, sex and school

Table 7. Univariate analysis between SARS-CoV-2 infection and contact patterns of students and staff from sentinel schools. Catalonia, Spain, February-March 2021.

Variables	Students				Staff				Total				Univariate analysis	
	Positive N=180		Negative N=1827		Positive N=41		Negative N=479		Positive N=221		Negative N=2306		Prevalence ratio	p-value
	n	%	n	%	n	%	n	%	n	%	n	%		
Lives with healthcare professional														
No	163	91.1	1598	87.9	35	94.6	407	92.7	198	91.7	2005	88.8	ref	
Yes	16	8.9	221	12.1	2	5.4	32	7.3	18	8.3	253	11.2	0.77 (0.49-1.22)	0.262
Unspecific contact with suspected cases of COVID-19														
Don't know	24	13.4	599	33.0	13	31.7	192	40.2	37	16.8	791	34.5	ref	
No	21	11.7	493	27.2	4	9.8	117	24.5	25	11.4	610	26.6	0.79 (0.49-1.29)	0.349
Yes	134	74.9	722	39.8	24	58.5	169	35.4	158	71.8	891	38.9	2.76 (1.94-3.93)	<0.001
Contact with suspected cases of COVID-19 at home														
No	52	38.8	425	59.3	12	50.0	123	72.8	64	40.5	548	61.9	ref	
Yes	82	61.2	292	40.7	12	50.0	46	27.2	94	59.5	338	38.1	2.17 (1.62-2.91)	<0.001
Contact with suspected cases of COVID-19 at school														
No	66	49.3	295	41.1	15	62.5	56	33.1	81	51.3	351	39.6	ref	
Yes	68	50.7	422	58.9	9	37.5	113	66.9	77	48.7	535	60.4	0.60 (0.45-0.80)	<0.001
Avoiding contact in crowded spaces*														
No	26	14.4	170	9.5	4	10.0	23	4.9	30	13.6	193	8.5		
Yes	154	85.6	1625	90.5	36	90.0	452	95.2	190	86.4	2077	91.5	0.65 (0.45-0.93)	0.019
Self-reported health status**														
Low	8	4.4	27	1.5	2	4.9	22	4.6	10	4.5	49	2.1	ref	
High	172	95.6	1794	98.5	39	95.1	457	95.4	211	95.5	2251	97.9	0.55 (0.30-1.01)	0.053

* Likert scale. No: never, almost never or sometimes; Yes: most of the time or always

** Likert scale. Low: 1-4; High: 5-7

*** GLM adjusted Poisson model with robust error and adjustment for age, sex and school

In the multivariate analysis, the same significance and trend among socioeconomic, health measures and contact patterns variables were observed (Table 8).

Table 8. Multivariate analysis between SARS-CoV-2 infection, sociodemographic and health indicators, by students and staff from sentinel schools. Catalonia, February to March 2021.

Variables	Estimate	CI_low	CI_upp	p-value
Contact pattern	2.205	1.876	2.591	<0.001
Perceived gravity if infected with coronavirus	1.328	1.011	1.744	0.041
Be employed	1.348	1.009	1.801	0.043
Compliance of sanitary measures	0.547	0.372	0.805	0.002
Self-reported health status	0.432	0.221	0.845	0.014
Use of transport public or school bus	0.522	0.327	0.836	0.007
Parents educational level (higher)	0.726	0.554	0.953	0.021

Incidence and univariate analysis at the longitudinal component

During the longitudinal component of the study, 45 new infections occurred (34 students and 11 staff), 11 of them identified by RT-PCR performed by the project team and 34 self-reported in by the participants. It is interesting to note that out of 11 RT-PCR positives identified in the study, only 1 (9%) was also detected by RAT.

The overall incidence was 2.73 (95% CI 1.991, 3.653) per 100 person-month, that is 2.887 (95% CI 1.999, 4.034) and 2.337 (95% CI 1.167, 4.182) per 100 person-month for students and staff, respectively.

The variables included in the univariate analysis were also categorized into sociodemographic and socioeconomic indicators, health status, and preventive compliance. There was a protective behavior associated with socioeconomic status, when comparing the highest level (high) in reference to the first tercile (low) (RR 0.25, 95% CI 0.06-0.96) for the COVID-19 infection (Table 9).

Table 9. Longitudinal component results by follow-up endpoint and relative risk adjusted by sex and age, of risk factors for SARS-CoV-2 infection in participants of the longitudinal component. Sentinel schools project, Catalonia, Spain, April to June 2021.

Variables	Round 1		Round 2		Round 3		Round 4		Univariate analysis									
	Positive N=10		Negative N=1250		Positive N=14		Negative N=1182		Positive N=6		Negative N=1118		Positive N=15		Negative N=1127		RR (95% CI)	p-value
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%		
Socioeconomic																		
Sex																		
Female	4	40.0	815	65.2	5	35.7	761	64.4	5	83.3	709	63.4	10	66.7	722	64.1	-	-
Male	6	60.0	435	34.8	9	64.3	421	35.6	1	16.7	409	36.6	5	33.3	405	35.9	-	-
Age - years [IQR]	15.5 [14.2;16.8]		16.0 [14.0;31.0]		15.0 [13.0;16.0]		16.0 [14.0;32.0]		14.5 [12.5;34.5]		16.0 [13.0;32.0]		16.0 [14.0;34.5]		16.0 [14.0;34.0]		-	-
Socioeconomic level																		
Low	5	50.0	657	53.2	10	71.4	629	53.9	2	33.3	553	50.1	8	53.3	587	52.9	ref	
Middle	4	40.0	351	28.4	3	21.4	319	27.4	4	66.7	336	30.4	6	40.0	324	29.2	0.91 (0.43-1.93)	0.814
High	1	10.0	226	18.3	1	7.14	218	18.7	0	0.0	215	19.5	1	6.7	199	17.9	0.25 (0.06-0.96)	0.044
Contact pattern*																		
Had contact																		
Don't know	3	33.3	607	59.4	4	36.4	452	60.6	2	33.3	247	60.4	8	66.7	341	69.0	ref	
No	4	44.4	347	34.0	2	18.2	247	33.1	0	0.0	132	32.3	2	16.7	134	27.1	0.74 (0.32-1.75)	0.497
Yes	2	22.2	68	6.7	5	45.5	47	6.3	4	66.7	30	7.33	2	16.7	19	3.9	6.44 (3.15-13.19)	<0.001
Contact at home																		
No	8	88.9	1001	97.9	8	72.7	742	99.5	4	66.7	400	97.8	11	91.7	492	99.6	ref	
Yes	1	11.1	21	2.1	3	27.3	4	0.5	2	33.3	9	2.2	1	8.3	2	0.40	12.42 (5.81-26.52)	<0.001
Contact at school																		
No	8	88.9	985	96.4	10	90.9	710	95.2	4	66.7	396	96.8	11	91.7	479	97.0	ref	
Yes	1	11.1	37	3.6	1	9.1	36	4.8	2	33.3	13	3.2	1	8.3	15	3.0	3.73 (1.49-9.38)	0.005
Unspecific contact																		
No	8	88.9	990	96.9	9	81.8	729	97.7	4	66.7	400	97.8	12	100	490	99.2	ref	
Yes	1	11.1	32	3.1	2	18.2	17	2.3	2	33.3	9	2.2	0	0.0	4	0.8	5.28 (2.1-13.27)	<0.001
Health status																		
Chronic diseases																		
No	6	60.0	1083	86.8	13	92.9	1023	86.7	3	50.0	965	86.5	12	80.0	979	87.0	ref	
Yes	4	40.0	165	13.2	1	7.1	157	13.3	3	50.0	151	13.5	3	20.0	146	13.0	2.18 (1.1-4.33)	0.026

Preventive measures**

Wearing a mask

No	0	0.0	8	0.8	1	10.0	5	0.7	1	16.7	1	0.3	0	0.0	1	0.2	ref	
Yes	9	100	1012	99.2	9	90.0	741	99.3	5	83.3	404	99.8	11	100	490	99.8	0.14 (0.04-0.53)	0.004

Avoid contact*

No	2	22.2	43	4.5	1	10.0	39	5.6	1	16.7	20	5.3	1	9.1	25	5.5	ref	
Yes	7	77.8	921	95.5	9	90.0	656	94.4	5	83.3	361	94.8	10	90.9	429	94.5	0.38 (0.15-0.97)	0.043

* With people suspect, confirmed or at risk for COVID-19

** In the last 7 days

*** Calculated using an independent log binomial mixed model

Contact with a suspected or confirmed case of COVID-19, was a risk factor for infection (RR 6.44, 95% CI 3.15-13.19). When the contact occurred at home, the risk (RR 12.42, 95% CI 5.81-26.52) was higher than compared to school (RR 3.73, 95% CI 1.49-9.38) and other non-specific locations (RR 5.28, 95% CI 2.1-13.27).

We tested several sanitary measures that had been carried out in the last seven days before the survey and only *avoiding close contact with someone who is infected or at risk* (RR 0.38, 95% CI 0.15-0.97) and a *wearing mask* (RR 0.14, 95% CI 0.04-0.53) were associated, this is compatible with the also significant result of the variable *contact with a suspected or confirmed cases of COVID-19*.

We tested the feasibility of a twice a month RT-PCR testing strategy. Considering a prevalence of 0.07% and accuracy of 0.05) 1,258 participants should be tested to find one positive.

Discussion

In Switzerland, the “Ciao Corona” study, conducted in June/July 2020, October/November 2020, and March/April 2021 with 2,585 children, found 2.8% (95%CI 1.6-4.1%) SARS-CoV-2 IgG, IgM and IgA seroprevalence [26,27]. In Germany, a study conducted during May and June 2020 founded 0.6% seroprevalence for students and school staff and 0.7% at the follow up, in September/October 2020 [28]. A population study carried out with children under 18 years of age in Catalonia found a lower seroprevalence than what we found in our study, of 4.4% between March and April 2020. This difference may reflect the difficulty of diagnosing asymptomatic youngsters especially during the initial period of the pandemic, emphasizing the importance of active surveillance of school sentinel populations, for the timely detection of respiratory viruses [29].

As expected, in our study there was a significant increase in SARS-CoV-2 seroprevalence, in the school staff group, which can be explained by the increase of vaccination coverage. According to PADRIS data the vaccine coverage in school staff went from 78% and 0.6% in April 2021 to 84.3% and 35.6% in June 2022, partly and fully vaccinated respectively. At the time of seroprevalence data collection in this study, vaccines were not approved for people under 18 years.

The prevalence of active SARS-CoV-2 infections detected by the project was low considering the overall prevalence and incidence from Catalonia during the same period

[3,20,30,31]. This suggests that public health strategies such as testing of symptomatic individuals and contact tracing efforts were effective at identifying an active infection at school, even the asymptomatic population [28]. Another study proceeded during in December 2020, in a high community transmission period in Switzerland [17] found, a positive PCR in none of the teacher and one child and Antigen positive test in 7 (1.1%) children and 2 (3.0%).

Considering detected and self-reported infections in our longitudinal study we found a low incidence of COVID-19 infections, consistent with other studies that have very similar results to ours [28,32–34]. Also, there are studies suggesting that higher community incidence, diagnostic issues [30], demographic and economic aspects are determinants in the variation of different rates detected, as showed in these studies [16,35,36].

The association between socioeconomic status and SARS-CoV-2 infection was different depending on the period of data collection. First, at the beginning of the pandemic, improved economic situation was positively associated with having been infected. This could be explained by the fact that the most affected population were those who worked and travelled than those who were respecting the lockdown measures. Then, during the follow-up we observed a new trend where a higher infection risk was associated with lower economic status. This provides important clues to understanding the COVID-19 burden in different economic and demographic contexts [37]. Population-based studies found similar results where heterogeneity in incidence and mortality rates [32,35,36] were associated with socioeconomic status showing the importance of planning sanitary policies oriented to the territorial characteristics and specific inequities [38,39], such as in a follow-up study in Brazil that found a high incidence in children living in a slum area [16].

At baseline, contact with suspected or confirmed cases, especially at home, was positively associated with SARS-CoV-2 infection, as observed in a study that found that physical distancing measures, including limited close contacts while school remained open, controlled SARS-CoV-2 transmission [40]. However, school contacts had a negative association with this outcome, showing how well-implemented sanitary protocols make the safe opening of schools possible, consistent with other studies that found an association between low transmission and, sanitary recommendations and preventive measures [6,41].

In the longitudinal component analysis, all contact patterns were a risk factor, especially when contact was at home, consistent with previous studies that demonstrated an increased risk of infection associated with household contacts in Catalonia [15,31,42] and modeling studies that demonstrated an increased risk for infection in household contacts [43,44]. Even contact tracing studies found no typical or frequent child-adult transmission [16,45,46] and a low contribution of children in the secondary cases [47,48], which showed that children do not seem to be the main source of infection [11,49].

Interestingly, contact with healthcare professionals was not associated with the infections in our study. Our hypothesis to explain that is the compliance of preventive measures at home when health care workers were exposed to risk situations, however, we need more studies to understand the role of HCW in this transmission model.

Perceived knowledge was positively associated with infection, which may indicate either knowledge acquired due to a previous infection, or the large amount of lay knowledge consumed by the young and indeed the general population [49,50].

Knowledge of COVID-19 and risk perception may have been due to the occurrence of a previous infection, which would not explain the occurrence of a later infection. A high level of risk perception of exposure might indicate they understood the risks they had taken. Other studies also show that risk perceptions, behaviors and compliance with sanitary measures are associated with levels of knowledge [51–53].

As with other studies [15,17,47] our results reinforce that the transmission by children in the school setting did not appear to make a major contribution to the spread of the virus, especially for the youngest children. This supports the decision of many countries to keep schools open while following several public health measures and safety protocols to control the transmission of the virus. Our study also reinforces the idea that the strategy based on an active sentinel surveillance for detection of acute SARS-CoV-2 infections followed by isolation of bubble groups seems to be more effective in scenarios with susceptible groups and rapid transmission.

Approximately half of the target population agreed to participate and considering the difficult circumstances schools and families were experiencing because of the pandemic; we consider this proportion to be quite acceptable. As a matter of fact, it is similar to other studies where 75% and 25% of students and staff participated respectively [28] or with 49% of child participation [17].

Limitations

Although the overall participation rate in our study was 45.4%, it was proportionately higher among school staff (72%) than students (41%), this suggests that given the fact that higher sociodemographic heterogeneity (nationality, language, socioeconomic status) was higher among students than staff, some of these factors could have also influenced participation. There were no difficulties in implementing the study and all sentinel schools gave us excellent feedback for the associated activities.

Because of the sample of the schools and the participation rate, the study population may not be representative of all schools in Catalonia. Nevertheless, the heterogeneity of the included school's information from different socioeconomical scenarios with a big enough study population. As a sentinel population approach, the objective of the CSSNC is not to extrapolate parameters, but to complement formal epidemiological surveillance systems by means of monitoring them steadily over time population studied. The data presented were gathered before the Omicron variant circulation and therefore our findings may not apply during the Spanish sixth wave or other future scenarios related to potential new variants and vaccine recommendations for children.

As a cross-sectional design, association should be interpreted with caution, without attributing causality. Variables such as distal characteristics must be interpreted differently from variables that can change over time such as knowledge, behavior, and contact patterns, which are influenced by the occurrence of the disease. Moreover, the acceptability, compliance, and prevention behaviors, may have been directly affected by the course of the pandemic.

There were some limitations to our longitudinal analysis as the small number of acute infections made impossible to apply a multivariate analysis. Also, with community public health measures occurring simultaneously with the schools' own protocols it was difficult to evaluate these determinants separately. In addition, there was a poor distribution of confounders between groups, which can also have very different sizes, resulting in a loss of statistical power in a multivariate model.

Conclusions

This study offers a unique perspective on the prevalence and incidence of SARS-CoV-2 infection among students and school staff in Catalonia, an important result considering the difficulty of detecting the virus among asymptomatic young people, as well as regarding the compliance and effectiveness of public health measures implemented in these schools in the transmission of SARS-CoV-2.

The CSSNC demonstrated, for the first time in Spain, the feasibility of correlating individual socio-epidemiological data and data on the prevalence and incidence of SARS-CoV-2 in the school environment, even during the difficult acute period of the pandemic. Despite the high prevalence and community incidence of SARS-CoV-2 in Catalonia during the study period, this project found a low prevalence and incidence of active infections in the school population, suggesting that the prevention methods adopted by schools, together with other strategies of health care, such as testing and contact tracing, were effective in containing transmission in educational settings.

Monitoring of SARS-CoV-2 biological markers and their behavioral and structural determinants over time in sentinel schools is crucial to assess the situation of the COVID-19 pandemic and provide relevant information to inform guidelines and policies to increase safety among students and staff in school environments. Apart from identifying multilevel transmission determinants for SARS-CoV-2 among students and school staff, they may also be useful to describe the spread of other infectious diseases such as influenza and other respiratory viruses and facilitate healthier learning environments for all.

Finally, we emphasize the fundamental role of social determinants in the planning of health policies oriented towards territorial characteristics and promoting models and strategies that consider specific inequities.

The CSSNC has been useful to describe the dynamics of the SARS-CoV-2 infection and to identify some of its determinants among schools' settings in Catalonia during the acute phase of the pandemic and to reinforce the appropriateness of the prevention policy implemented during this period. Nevertheless, the future of the SARS-CoV-2 pandemic and the role of vaccines, particularly among children, is still uncertain and after the introduction of vaccines, seroprevalence need to be linked to vaccine information to be properly interpreted. In such context, we believe that to maintain in

place the experience and structure of the sentinel active surveillance as proposed by CSSNC as an enhanced surveillance tool may be useful not only for COVID-19 related policies and strategies, but for the monitorization and evaluation of other respiratory viruses and health problems which affects the school community.

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References

- [1] Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time. *Lancet Infect Dis* 2020;20:533–4. [https://doi.org/10.1016/S1473-3099\(20\)30120-1](https://doi.org/10.1016/S1473-3099(20)30120-1).
- [2] Coma E, Mora N, Méndez L, Benítez M, Hermsilla E, Fàbregas M, et al. Primary care in the time of COVID-19: Monitoring the effect of the pandemic and the lockdown measures on 34 quality of care indicators calculated for 288 primary care practices covering about 6 million people in Catalonia. *BMC Fam Pract* 2020;21:1–9. <https://doi.org/10.1186/S12875-020-01278-8/FIGURES/3>.

- [3] Generalitat de Catalunya. Datos abiertos y COVID-19. https://GubernobertGencatCat2022.https://gubernobert.gencat.cat/es/dades_obertes/dades-obertes-covid-19/ (accessed March 21, 2022).
- [4] Viner RM, Mytton OT, Bonell C, Melendez-Torres GJ, Ward J, Hudson L, et al. Susceptibility to SARS-CoV-2 Infection among Children and Adolescents Compared with Adults: A Systematic Review and Meta-Analysis. *JAMA Pediatr* 2021;175:143–56. <https://doi.org/10.1001/jamapediatrics.2020.4573>.
- [5] Yoon Y, Kim KR, Park H, Kim S, Kim YJ. Stepwise School Opening and an Impact on the Epidemiology of COVID-19 in the Children. *J Korean Med Sci* 2020;35. <https://doi.org/10.3346/JKMS.2020.35.E414>.
- [6] Esposito S, Cotugno N, Principi N. Comprehensive and safe school strategy during COVID-19 pandemic. *Ital J Pediatr* 2021;47:6. <https://doi.org/10.1186/s13052-021-00960-6>.
- [7] Luca G de, Kerckhove K van, Coletti P, Poletto C, Bossuyt N, Hens N, et al. The impact of regular school closure on seasonal influenza epidemics: A data-driven spatial transmission model for Belgium. *BMC Infect Dis* 2018;18. <https://doi.org/10.1186/s12879-017-2934-3>.
- [8] Cauchemez S, Valleron AJ, Boëlle PY, Flahault A, Ferguson NM. Estimating the impact of school closure on influenza transmission from Sentinel data. *Nature* 2008;452:750–4. <https://doi.org/10.1038/nature06732>.
- [9] Kawano S, Kakehashi M. Substantial impact of school closure on the transmission dynamics during the pandemic Flu H1N1-2009 in Oita, Japan. *PLoS One* 2015;10. <https://doi.org/10.1371/JOURNAL.PONE.0144839>.
- [10] Manivannan M, Jogalekar MP, Kavitha MS, Maran BAV, Gangadaran P. A mini-review on the effects of COVID-19 on younger individuals. *Exp Biol Med* 2021;246:293–7. <https://doi.org/10.1177/1535370220975118>.
- [11] Escosa-García L, Aguilera-Alonso D, Calvo C, Mellado MJ, Baquero-Artigao F. Ten key points about COVID-19 in children: The shadows on the wall. *Pediatr Pulmonol* 2020;55:2576–86. <https://doi.org/10.1002/ppul.25025>.

- [12] Bi Q, Wu Y, Mei S, Ye C, Zou X, Zhang Z, et al. Epidemiology and transmission of COVID-19 in 391 cases and 1286 of their close contacts in Shenzhen, China: a retrospective cohort study. *Lancet Infect Dis* 2020;20:911–9. [https://doi.org/10.1016/S1473-3099\(20\)30287-5](https://doi.org/10.1016/S1473-3099(20)30287-5).
- [13] Goldstein E, Lipsitch M, Cevik M. On the effect of age on the transmission of SARS-CoV-2 in households, schools, and the community. *Journal of Infectious Diseases* 2021;223:362–9. <https://doi.org/10.1093/infdis/jiaa691>.
- [14] Keeling MJ, Tildesley MJ, Atkins BD, Penman B, Southall E, Guyver-Fletcher G, et al. The impact of school reopening on the spread of COVID-19 in England. *Philosophical Transactions of the Royal Society B: Biological Sciences* 2021;376. <https://doi.org/10.1098/rstb.2020.0261>.
- [15] Soriano-Arandes A, Gatell A, Serrano P, Biosca M, Campillo F, Capdevila R, et al. Household Severe Acute Respiratory Syndrome Coronavirus 2 Transmission and Children: A Network Prospective Study. *Clin Infect Dis* 2021;73:e1261–9. <https://doi.org/10.1093/CID/CIAB228>.
- [16] Lugon amella, Fuller T, Damasceno L, Calvet G, Cristina Resende P, Rocha Matos A, et al. SARS-CoV-2 Infection Dynamics in Children and Household Contacts in a Slum in Rio de Janeiro ARTICLE. *Pediatrics* 2021;148:2021050182. <https://doi.org/10.1542/peds.2021-050182>.
- [17] Kriemler S, Ulyte A, Ammann P, Peralta GP, Berger C, Puhan MA, et al. Surveillance of Acute SARS-CoV-2 Infections in School Children and Point-Prevalence During a Time of High Community Transmission in Switzerland. *Front Pediatr* 2021;9. <https://doi.org/10.3389/fped.2021.645577>.
- [18] lo Moro G, Sinigaglia T, Bert F, Savatteri A, Gualano MR, Siliquini R. Reopening schools during the COVID-19 pandemic: Overview and rapid systematic review of guidelines and recommendations on preventive measures and the management of cases. *Int J Environ Res Public Health* 2020;17:1–21. <https://doi.org/10.3390/ijerph17238839>.
- [19] López-Bueno R, López-Sánchez GF, Casajús JA, Calatayud J, Tully MA, Smith L. Potential health-related behaviors for pre-school and school-aged children during COVID-19 lockdown: A narrative review. *Prev Med (Baltim)* 2021;143. <https://doi.org/10.1016/j.ypmed.2020.106349>.

- [20] Perramon A, Soriano-Arandes A, Pino D, Lazcano U, Andrés C, Català M, et al. Schools as a Framework for COVID-19 Epidemiological Surveillance of Children in Catalonia, Spain: A Population-Based Study. *Front Pediatr* 2021;9. <https://doi.org/10.3389/fped.2021.754744>.
- [21] Generalitat de Catalunya. Departament d'Educació. Gestió de casos de COVID-19 als centres educatius 2020:1–26.
- [22] Generalitat de Catalunya. Departament de Salut. Procediment d'actuació enfront de casos d'infecció pel nou coronavirus SARS-CoV-2. 2020.
- [23] Zhang J, Litvinova M, Liang Y, Wang Y, Wang W, Zhao S, et al. Changes in contact patterns shape the dynamics of the COVID-19 outbreak in China. *Science* (1979) 2020;368:1481–6. <https://doi.org/10.1126/science.abb8001>.
- [24] Bordas A, Soriano-Arandes A, Subirana M, Malagrida R, Reyes-Urueña JM, Folch C, et al. Study protocol for monitoring SARS-CoV-2 infection and its determinants in Catalonia (Spain): an observational and participatory research approach in a Sentinel Network of Schools. *BMJ Open* 2022;12:e055649. <https://doi.org/10.1136/bmjopen-2021-055649>.
- [25] Betsch C, Wieler LH, Habersaat K. Monitoring behavioural insights related to COVID-19. *The Lancet* 2020;395:1255–6. [https://doi.org/10.1016/S0140-6736\(20\)30729-7](https://doi.org/10.1016/S0140-6736(20)30729-7).
- [26] Ulyte A, Radtke T, Abela IA, Haile SR, Braun J, Jung R, et al. Seroprevalence and immunity of SARS-CoV-2 infection in children and adolescents in schools in Switzerland: design for a longitudinal, school-based prospective cohort study. *Int J Public Health* 2020;65:1549–57. <https://doi.org/10.1007/s00038-020-01495-z>.
- [27] Ulyte A, Radtke T, Abela IA, Haile SR, Berger C, Huber M, et al. Clustering and longitudinal change in SARS-CoV-2 seroprevalence in school children in the canton of Zurich, Switzerland: Prospective cohort study of 55 schools. *The BMJ* 2021;372. <https://doi.org/10.1136/bmj.n616>.
- [28] Kirsten C, Unrath M, Lück C, Dalpke AH, Berner R, Armann J. SARS-CoV-2 seroprevalence in students and teachers: a longitudinal study from May to October 2020 in German secondary schools. *BMJ Open* 2021;11:49876. <https://doi.org/10.1136/bmjopen-2021-049876>.

- [29] Edward Burn, Cristian Tebé, Sergio Fernandez-Bertolin, Maria Aragon, Martina Recalde, Elena Roel, et al. The natural history of symptomatic COVID-19 during the first wave in Catalonia. *Nat Commun* 2021;17:1–13.
- [30] Lluçà A, Borràs-Santos A, Guinovart C, Utzet M, Moriña D, Puig J. SARS-CoV-2 transmission in students of public schools of Catalonia (Spain) after a month of reopening. *PLoS One* 2021;16:e0251593. <https://doi.org/10.1371/journal.pone.0251593>.
- [31] Pollán M, Pérez-Gómez B, Pastor-Barriuso R, Oteo J, Hernán MA, Pérez-Olmeda M, et al. Prevalence of SARS-CoV-2 in Spain (ENE-COVID): a nationwide, population-based seroepidemiological study. *The Lancet* 2020;396:535–44. [https://doi.org/10.1016/S0140-6736\(20\)31483-5](https://doi.org/10.1016/S0140-6736(20)31483-5).
- [32] Choe YJ, Park Y-J, Kim E-Y, Jo M, Cho EY, Lee H, et al. SARS-CoV-2 transmission in schools in Korea: nationwide cohort study. *Arch Dis Child* 2021;0:1–5. <https://doi.org/10.1136/archdischild-2021-322355>.
- [33] Tönshoff B, Müller B, Elling R, Renk H, Meissner P, Hengel H, et al. Prevalence of SARS-CoV-2 Infection in Children and Their Parents in Southwest Germany. *JAMA Pediatr* 2021;175:586. <https://doi.org/10.1001/jamapediatrics.2021.0001>.
- [34] van Loon W, Theuring S, Hommes F, Mall MA, Seybold J, Kurth T, et al. Prevalence of SARS-CoV-2 Infections among Students, Teachers, and Household Members during Lockdown and Split Classes in Berlin, Germany. *JAMA Netw Open* 2021. <https://doi.org/10.1001/jamanetworkopen.2021.27168>.
- [35] Mena GE, Martínez PP, Mahmud AS, Marquet PA, Buckee CO, Santillana M. Socioeconomic status determines COVID-19 incidence and related mortality in Santiago, Chile. *Science (1979)* 2021;372. <https://doi.org/10.1126/science.abg5298>.
- [36] Riou J, Panczak R, Althaus CL, Junker C, Perisa D, Schneider K, et al. Socioeconomic position and the COVID-19 care cascade from testing to mortality in Switzerland: a population-based analysis. *Lancet Public Health* 2021;6:e683–91. [https://doi.org/10.1016/S2468-2667\(21\)00160-2](https://doi.org/10.1016/S2468-2667(21)00160-2).
- [37] Marí-Dell’Olmo M, Gotsens M, Pasarín MI, Rodríguez-Sanz M, Artazcoz L, García de Olalla P, et al. Socioeconomic Inequalities in COVID-19 in a European Urban Area: Two Waves, Two Patterns. *Int J Environ Res Public Health* 2021;18:1256. <https://doi.org/10.3390/ijerph18031256>.

- [38] Im Kampe EO, Lehfeld AS, Buda S, Buchholz U, Haas W. Surveillance of COVID-19 school outbreaks, Germany, March to August 2020. *Eurosurveillance* 2020;25. <https://doi.org/10.2807/1560-7917.ES.2020.25.38.2001645>.
- [39] Julieta Politi, Mario Martín-Sánchez, Lilas Mercuriali, Blanca Borrás-Bermejo, Joaquín Lopez-Contreras, Anna Vilella, et al. Epidemiological characteristics and outcomes of COVID-19 cases: mortality inequalities by socioeconomic status, Barcelona, Spain, 24 February to 4 May 2020. *Eurosurveillance* 2021;26. <https://doi.org/10.2807/1560-7917>.
- [40] Ingelbeen B, Peckeu L, Laga M, Hendrix I, Neven I, van der Sande MAB, et al. Reducing contacts to stop SARS-CoV-2 transmission during the second pandemic wave in Brussels, Belgium, August to November 2020. *Eurosurveillance* 2021;26. <https://doi.org/10.2807/1560-7917.ES.2021.26.7.2100065>.
- [41] Ehrhardt J, Ekinici A, Krehl H, Meincke M, Finci I, Klein J, et al. Transmission of SARS-CoV-2 in children aged 0 to 19 years in childcare facilities and schools after their reopening in May 2020, Baden-Württemberg, Germany. *Eurosurveillance* 2020;25. <https://doi.org/10.2807/1560-7917.ES.2020.25.36.2001587>.
- [42] Marks M, Millat-Martinez P, Ouchi D, Roberts C h., Alemany A, Corbacho-Monné M, et al. Transmission of COVID-19 in 282 clusters in Catalonia, Spain: a cohort study. *Lancet Infect Dis* 2021;21:629–36. [https://doi.org/10.1016/S1473-3099\(20\)30985-3/ATTACHMENT/59270188-9308-4D12-9A13-4C1F5A58D3BB/MMC2.PDF](https://doi.org/10.1016/S1473-3099(20)30985-3/ATTACHMENT/59270188-9308-4D12-9A13-4C1F5A58D3BB/MMC2.PDF).
- [43] Kim S, Kim Y-J, Peck KR, Jung E. School Opening Delay Effect on Transmission Dynamics of Coronavirus Disease 2019 in Korea: Based on Mathematical Modeling and Simulation Study. *J Korean Med Sci* 2020;35. <https://doi.org/10.3346/jkms.2020.35.e143>.
- [44] Munday JD, Jarvis CI, Gimma A, Wong KLM, van Zandvoort K, Liu Y, et al. Estimating the impact of reopening schools on the reproduction number of SARS-CoV-2 in England, using weekly contact survey data. *BMC Med* 2021;19. <https://doi.org/10.1186/s12916-021-02107-0>.
- [45] Yi S, Kim Y-M, Choe YJ, Ahn S, Han S, Park Y-J. Geospatial Analysis of Age-specific SARS-CoV-2 Transmission Patterns in Households, Korea. *J Korean Med Sci* 2021;36. <https://doi.org/10.3346/jkms.2021.36.e63>.

- [46] Zimmerman KO, Akinboyo IC, Brookhart MA, Boutzoukas AE, McGann KA, Smith MJ, et al. Incidence and Secondary Transmission of SARS-CoV-2 Infections in Schools. *Pediatrics* 2021;147:e2020048090. <https://doi.org/10.1542/peds.2020-048090>.
- [47] Ertem Z, Schechter-Perkins EM, Oster E, Berg P, Epshtein I, Chaiyakunapruk N, et al. The impact of school opening model on SARS-CoV-2 community incidence and mortality. *Nat Med* 2021;27:2120–6. <https://doi.org/10.1038/s41591-021-01563-8>.
- [48] Park YJ, Choe YJ, Park O, Park SY, Kim Y-M, Kim J, et al. Contact Tracing during Coronavirus Disease Outbreak, South Korea, 2020. *Emerg Infect Dis* 2020;26:2465–8. <https://doi.org/10.3201/eid2610.201315>.
- [49] Ismail SA, Saliba V, Lopez Bernal J, Ramsay ME, Ladhani SN. SARS-CoV-2 infection and transmission in educational settings: a prospective, cross-sectional analysis of infection clusters and outbreaks in England. *Lancet Infect Dis* 2021;21:344–53. [https://doi.org/10.1016/S1473-3099\(20\)30882-3](https://doi.org/10.1016/S1473-3099(20)30882-3).
- [50] Hatami H, Abbasi-Kangevari M, Malekpour M-R, Kolahi A-A. Knowledge, Attitudes, and Safety Practices About COVID-19 Among High School Students in Iran During the First Wave of the Pandemic. *Front Public Health* 2021;9. <https://doi.org/10.3389/fpubh.2021.680514>.
- [51] Lee M, Kang B-A, You M. Knowledge, attitudes, and practices (KAP) toward COVID-19: a cross-sectional study in South Korea. *BMC Public Health* 2021;21:295. <https://doi.org/10.1186/s12889-021-10285-y>.
- [52] Reuben RC, Danladi MMA, Saleh DA, Ejembi PE. Knowledge, Attitudes and Practices Towards COVID-19: An Epidemiological Survey in North-Central Nigeria. *J Community Health* 2021;46:457–70. <https://doi.org/10.1007/s10900-020-00881-1>.
- [53] Shrestha A, Thapa TB, Giri M, Kumar S, Dhobi S, Thapa H, et al. Knowledge and attitude on prevention of COVID-19 among community health workers in Nepal-a cross-sectional study. *BMC Public Health* 2021;21:1424. <https://doi.org/10.1186/s12889-021-11400-9>.

ARTICLE 2

Determinants of COVID-19 vaccine hesitancy among students and parents in Sentinel Schools Network of Catalonia, Spain

SUMMARY

Objective of the study: The objectives of this study are to describe the COVID-19 vaccine acceptance, intentions and the key reasons for hesitation and refusal among students over 16 years and parents of students under 16 years, in the CSSNC, during the academic year 2021–2022, as well as to identify potential multilevel determinants for these parameters.

Study design: A cross-sectional study conducted in October 2021 and January 2022, in 23 schools participating in the CSSNC.

Study population: In the first endpoint 3,383 students were included, aged 3–4 years (n =213); 5–11 years (n =1085); 12–15 years (n =860) and 16–18 years (n =1,225). In January 2022 there were, 2,635 students, aged 3–4 years (n =196); 5–11 years (n =1,035); 12–15 years (n =834) and over16 years (n =570 over).

Data collection: Data collection was carried out in October 2021 and January 2022. through an online questionnaire available in Catalan, Spanish and English.

Variables, outcome and case definitions: The questionnaire contained questions about socioeconomic and demographic characteristics, behavior, compliance with preventive measures, impacts of the pandemic and vaccination status. Our first outcome was vaccination status, as vaccinated, we considered those with at least one dose of COVID-19 vaccine and unvaccinated, individuals with no dose. Regarding the vaccine intention, vaccine acceptance was used to describe a participant vaccinated with at least one dose of the COVID-19 vaccine or unvaccinated but with the intention of being vaccinated soon. We used vaccine hesitancy to describe unvaccinated participants, who were unsure whether they would be vaccinated and vaccine refusal to refers to all unvaccinated participants who expressed total refusal to be vaccinated. Our second was outcome vaccine acceptability, defined as “Yes” if participant was vaccinated with at least one dose of the COVID-19 vaccine or unvaccinated but with the intention of being vaccinated soon (vaccine acceptance) and as “No” for unvaccinated participants who were unsure whether they would be vaccinated (vaccine hesitancy) or unvaccinated participants who expressed total refusal to be vaccinated (vaccine refusal). We investigated the association between characteristics and factors that could influence the intention of adolescents to get vaccinated and of parents to allow their children to be vaccinated against SARS-CoV-2. These factors were referred as independent variables including the following categories:

sociodemographic, health, knowledge, attitudes and practices, measures to avoid aSARS-CoV-2 infection and COVID-19 related impacts.

Data analysis: Prior to analysis, we performed an imputation of multiple data sets by the chained equation method, obtaining 20 imputed datasets that allowed proceed univariate and multivariate analyzes with the same participants. The univariate analysis was adjusted for a3–15-year age group, using a binomial logistic regression, pooling the results through Rubin’s Rules (RR). A multivariate analysis was performed only with the parents’ database (students under 16 year) due to the low number of unvaccinated students over 16 years (n =24). We tested multicollinearity for each variable, excluding those with a correlation coefficient greater than 0.8 in absolute value. In the multivariate model we proceed a Deletion Substitution Addition (DSA), an algorithm for Machine Learning that chooses the model with the smallest Root Mean Square Error (RMSE). The performance of the models was accessed by the Akaike Information Criterion (AIC), adjusted R-square, criteria that defined the choice for the DSA model. We performed a McNemar test, which selects participants who were matched in the two samples (N =2,145), to see if there was significance between the difference in acceptability rates between October 2021 and January 2022 between parents and students.

Results: The vaccination coverage against SARS-CoV-2 in CSSNC was 36.1% for students under 16 years and 92.4% for students over 16 years in October 2021, increasing to 70.8% and 95.8% <16y-old and >16y-old, respectively, in January 2022. Among unvaccinated students over 16 years 28 (30.1%) and 15 (62.5%), in October and January respectively, refused to be vaccinated. The acceptability among their parents was proportionally higher among students aged 5–11 in October (70.2%) and students aged 3–4 in January (47.8%) but considering the denominators this result must be interpreted with caution, the parents’ intention also varied significantly between October 2021 and January 2022, according to the McNemar test.

We investigated the reasons for hesitation or refusal among parents and students in this study. The 11 key reasons informed by parents in both endpoints, were quite similar, concerning about side effects (67.1% and 57.4% respectively); insufficient research about vaccine safety and efficacy in children (52.1% and 50.4% respectively) and demand for more information to deciding to vaccinate their children (53.5% and 34.5% respectively). For students, the key reasons to hesitancy or refusal were slightly different in the two periods. In October 2021 most unvaccinated students reported concern with the time to

development the vaccine (63.6%), concern about side effects (50.9%) and necessity for more information before deciding to vaccinate (45.5%). In January 2022, the main reason was concerning about side effects (68.4%), time to development the vaccine (63.2%) and previous COVID-19 disease (42.1%)

The perception that it is easy to avoid aSARS-CoV-2 infection (OR 0.29 95%CI 0.09–0.88) and the use of herbal supplements and homeopathies to avoid aSARS-CoV-2 infection (OR 0.22 95%CI 0.08–0.63) were negatively associated with vaccine acceptance. A higher self-perceived knowledge (OR 3.6 95%CI 1.27–10.11) were positively associated with acceptability. As expected, adherence to vaccination strategies overall (OR 15.23 95%CI 5.13–45.19) and routine vaccination behavior (OR 5.49 95%CI 2.08–14.49) was strongly and positively associated with vaccine acceptability.

A negative association was found between COVID-19 vaccine acceptability and birthplace, when at least one of the parents was born outside Spain (OR 0.63 95%CI 0.46–0.86), houses with more than five people living together (OR 0.7 95%CI 0.49–0.99), decrease of family's economic situation during the pandemic (OR 0.65 95%CI 0.47–0.9), use of herbal supplement or homeopathy as a measure to prevent aSARS-CoV-2 infection (OR 0.44 95%CI 0.29–0.67), concern about spending too much time with family (OR 0.53 95%CI 0.29–0.97). A positive association was found between COVID-19 vaccine acceptability and when father (OR 2.45 95%CI 1.46–4.1) or mother (OR 1.68 95%CI 1.14–2.47) were employed, living with a healthcare work (OR 1.52 95%CI 1.03–2.25), a good perception about their current health status (OR 4.68 95%CI 1.16–18.84) and, adherence to vaccination strategies (OR 18.8 95%CI 6.93–50.98) and vaccination routine behavior (OR 2.7 95%CI 1.08–6.75).

In the multivariate analyses, the variables associated with vaccine acceptability were age, adherence to previous vaccination, father work situation, influence of health care workers. Variables associated with refusal or hesitancy was use of herbal supplements and homeopathies. The AIC for the DSA model was 1504.17 (SD =11.47), mean of the 20 imputed data sets, and the adjusted mean R-square was 0.2 (SD =0.006), which corresponds to the variability of the R-square obtained by the models of each of the imputed data sets, and suggests that similar results were obtained across all imputed datasets and may be an indicator of a high-quality imputation process.

Determinants of COVID-19 vaccine hesitancy among students and parents in Sentinel Schools Network of Catalonia, Spain

Short Title: Adolescents and parents COVID-19 vaccine hesitancy

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Abstract

Vaccine hesitancy is defined as a delay in acceptance of vaccines despite its availability, caused by many determinants. Our study presents the key reasons, determinants and characteristics associated with COVID-19 vaccine acceptability among students over 16 years and parents of students under 16 years and describe the COVID-19 vaccination among students in the settings of sentinel schools of Catalonia, Spain. This is a cross-sectional study that includes 3,383 students and the parents between October 2021 and January 2022. We describe the student's vaccination status and proceed a univariate and multivariate analysis using a Deletion Substitution Addition (DSA) machine learning algorithm. Vaccination against COVID-19 reached 70.8% in students under 16 years and 95.8% in students over 16 years at the end of the study project. The acceptability among unvaccinated students was 40.9% and 20.8% in October and January, respectively, and among parents was proportionally higher among students aged 5-11 (70.2%) in October and aged 3-4 (47.8%) in January. The key reason to not vaccinate themselves, or their children, were concern about side effects, insufficient research about the effect of the vaccine in children, rapid development of vaccines, necessity for more information and previous infection by SARS-CoV-2. Several variables were associated with refusal and hesitancy. For students, the main ones were risk perception and use of alternative therapies. For parents, the age of students, sociodemographic variables, socioeconomic impact related to the pandemic, and use of alternative therapies were more evident. Monitoring vaccine acceptance and refusal among children and their parents has been important to understand the interaction between different multilevel determinants and we hope it will be useful to improve public health strategies for future interventions in this population.

Key words: COVID-19, SARS-CoV-2, vaccine hesitancy, parents, adolescents, cross-sectional studies, machine learning

Introduction

During the Coronavirus disease (COVID-19) emergency caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), different public health measures were implemented across the world, especially when the development of a vaccine was still quite immature. Currently, in a different scenario, several countries have been cooperating for the rapid development, update and distribution of vaccines, and the raised concerns has become the impact on vaccine effectiveness, considering the SARS-CoV-2 variants, like Omicron and its sub-lineages, able to reinfect people with previous infection or even fully vaccinated against COVID-19 (1,2), as well as to guarantee their equitable distribution, acceptability (3,4) assessing the barriers to effectiveness of vaccination programs, such as vaccine hesitancy (5).

On December 21, 2020, the European Commission authorized the first vaccine against SARS-CoV-2, the Comirnaty Pfizer-BioNTec for people over 18 years, after the positive opinion of the European Medicines Agency (EMA). On December 27, 2020, the vaccination started in Spain prioritizing specific and vulnerable groups such health care workers (HCW), school staff, older and people with underlying diseases (6).

In May 2021, EMA recommended an extension for the Comirnaty COVID-19 vaccine to 12 to 15 years and in November 2021 for children aged 5 to 11 years making it available for these groups (7).

Catalonia, a Northeast region of Spain with 7.7 million inhabitants, has registered 2.6 million SARS-CoV-2 infections, 118 thousand hospitalizations and 28 thousand deaths since it's their first confirmed case on February 25, 2020. Vaccination coverage in Catalonia until November 2022 has reached 86.5% in people over 12 years, 79.5% in the 12-19 years and 33.7% in 5-11 (8).

Vaccine hesitancy was defined by the Strategic Advisory Group of Experts on Immunization (SAGE) as a “delay in acceptance or refusal of vaccines despite availability of vaccination services” that can be influenced by many factors such as the lack of offer, communication and confidence (9) and it is commonly observed with new vaccine or vaccine candidate (5). There is mounting evidence showing that vaccination can promote

an important control on burden and mortality caused by infectious diseases (10–12). Therefore, vaccination is a cost-benefit intervention, being hesitation and vaccine refusal an important concern to public health.

Several studies were estimated the vaccine hesitancy among different populations. In June 2021, the prevalence of COVID-19 vaccine hesitancy in Spain was estimated at 6.22%, the lowest eight European countries studied (11).

Despite differences between countries, significantly associations between vaccine hesitancy and sociodemographic determinants (Hassan et al. 2021), vaccine confidence and distrust, misinformation, beliefs towards COVID-19 vaccination have already been observed in other studies (5). A study that enrolled Asian, African and South America countries, founded that age, income, religion, comorbidities, economic situation during the COVID-19 pandemic and adherence to vaccination benefits were associated with COVID-19 vaccine hesitance (14), while in a study with European countries, gender, age, employment status, educational levels and vaccine skepticism, risk perception and compliance of public health measures and were associated with vaccine hesitance (11).

Epidemiological studies assessing determinants associated with the intention to vaccinate against SARS-CoV-2 may help to guide strategies for achieving the coverage that is necessary to avoid severity and mortality by COVID-19, and that could prevent the resurgence of this vaccine preventable disease (9,11,15–18).

Regarding the increasing burden of disease among children and young people, evidence suggests that the risk of long-term negative effects of COVID-19 in children is greater than the potential risks associated with vaccination against COVID-19 (19–21), immunization strategies against COVID-19 for children and adolescents must emphasize individual risks and benefits, recognizing for example, the emergence of more transmissible variants, such as Omicron (22,23). There is a debate about the real benefit-risk of COVID-19 vaccines in children/adolescents, due to a lower susceptibility to infection or COVID-19 observed in this population when compared with adults, the recommendation to vaccinate everyone aged 12 and over against COVID-19 has established itself as a critical strategy to control the pandemic (21).

This study is part of the COVID-19 Sentinel Schools Network of Catalonia (CSSNC) project, whose main objective are to monitor actively SARS-CoV-2 infections and identify barriers and facilitators for SARS-CoV-2 prevention strategies in schools.

The CSSNC also provides an active surveillance during the pandemic that gathered evidence for enhanced of health protocols to prevent the spread of SARS-CoV-2 and others respiratory virus in the school (24).

The objectives of this study are to describe the COVID-19 vaccine acceptance, intentions and the key reasons for hesitation and refusal among students over 16 years and parents of students under 16 years, in the CSSNC, during the academic year 2021-2022, as well as to identify potential multilevel determinants for these parameters.

Materials and methods

Study design and population

This cross-sectional study was conducted in two different periods, October 2021 and on January 2022, in a setting of 23 schools participating in the CSSNC. In the first endpoint 3,383 students were included, aged 3-4 years (n=213); 5-11 years (n=1085); 12-15 years (n=860) and 16-18 years (n=1,225). In January 2022 there were, 2,635 students, aged 3-4 years (n=196); 5-11 years (n=1,035); 12-15 years (n=834) and over16 years (n=570 over).

Data collection

Data collection was carried out in two points of time, the first in October 2021 and the second in January 2022. We collected nominal data through an online questionnaire, but a paper version was provided when necessary, and the questionnaires were also available in Catalan, Spanish and English. Two survey models were developed, one for students under 16 years, and another for students over 16 years.

The questionnaire contained questions about socioeconomic and demographic characteristics, behavior, compliance with preventive measures, impacts of the pandemic and vaccination status, and was adapted from the COSMO study survey (25).

For unvaccinated participants we asked if they would accept to receive the COVID-19 vaccine in the following months, whose response options were *accept*, *refuse* and *don't know*. For those who expressed hesitancy and refusal intentions, we also asked about the reason.

The online questionnaire was prepared using REDCap, we shared it through a link with the school management team so that it could be sent to all students, parents or

guardians and school staff. In addition, information panels were placed in schools, which included access to the survey via QR code. Before completing the survey, participants had to sign informed consent either in online or paper formats. In the second data collection, people who were already part of the project received the survey in their informed email.

The field team consisted of health professionals and researchers. Before starting the fieldwork, a series of sensitization meetings were held to inform the school community about the objectives of the study. In each school where participants were recruited, online and face-to-face meetings were held about the study with the participation of the project team and the educational community (families, teachers and school staff).

All participants under 16 years were guided by their parents or guardians, who answered the questionnaire and signed the informed consent. Students over 16 years answered the questionnaire and signed the informed consent by themselves. For this reason, we present the outcomes for the following groups: students older than 16 years (vaccination status and intentions), students younger than 16 years (vaccination status) and parents of students younger than 16 years (vaccination intentions).

Outcomes and case definition

Our first outcome was vaccination status, as *vaccinated*, we considered those with at least one dose of COVID-19 vaccine and *unvaccinated*, individuals with no dose.

Regarding the vaccine intention, *vaccine acceptance* was used to describe a participant vaccinated with at least one dose of the COVID-19 vaccine or unvaccinated but with the intention of being vaccinated soon. We used *vaccine hesitancy* to describe unvaccinated participants, who were unsure whether they would be vaccinated and *vaccine refusal* to refers to all unvaccinated participants who expressed total refusal to be vaccinated.

Our second was outcome *vaccine acceptability*, defined as “Yes” if a participant was vaccinated with at least one dose of the COVID-19 vaccine or unvaccinated but with the intention of being vaccinated soon (*vaccine acceptance*) and as “No” for unvaccinated participants who were unsure whether they would be vaccinated (*vaccine hesitancy*) or unvaccinated participants who expressed total refusal to be vaccinated (*vaccine refusal*).

Independent variables

We investigated the association between characteristics and factors that could influence the intention of adolescents to get vaccinated and of parents to allow their children to be vaccinated against SARS-CoV-2. These factors were referred as independent variables including the following categories: sociodemographic, health, knowledge, attitudes and practices, measures to avoid a SARS-CoV-2 infection and COVID-19 related impacts. Each variable was categorized according to the question asked in the questionnaire (Table 1).

Table 1. Independent variables included in the study, CSSNC Catalonia, Spain 2021-2022.

Sociodemographic	
Sex	Male / Female
Age *	Grouped: 3-4 / 5-11 / 12-15 years / ≥ 16 years
Student and parents' immigration status (birthplace)	Dichotomized: Spain / outside Spain (another countries)
Parents' employment situation	Dichotomized: Employed / unemployed, retired and lay-off
Parents' educational level	High education (university) / Secondary school / None or primary school
House size (in meters)	Dichotomized: $>70m^2$ / $<70m^2$
Residence size - People living in the same residence	Dichotomized: 1-4 / 5-9
Live with small/underage children	yes / no
Living with people over 65 years old	yes / no
Living with a healthcare work (HCW)	yes / no
Health	
Perception about current health status	Dichotomized: Bad (bad and fair) / Good (good, very good and excellent)
Perception about current mental health	Dichotomized: Bad (bad and fair) / Good (good, very good and excellent)
Have a chronic illness	yes / no
Previous COVID-19	No (No, and I had a negative test, I don't know) / Yes (and I had a positive test)
Knowledge, attitudes and practices	
Perceived risk to become infected with SARS-CoV-2	Likert scale Dichotomized: unlikely (1-4) / very likely (5-7)
Perceived severity if get infected with SARS-CoV-2	Likert scale Dichotomized: little severity (1-4) / very severity (5-7)
Avoid a SARS-CoV-2 infection during the pandemic is	Likert scale Dichotomized difficult (1-4) / easy (5-7)
Avoid SARS-CoV-2 infection in children during the pandemic	Likert scale Dichotomized Difficult (1-4) / easy (5-7)
Avoided contact with vulnerable people	Dichotomized Yes (most of the time and always) / No (sometimes, almost never and no)
Self-perceived knowledge about COVID-19 (a)	Likert scale Dichotomized: low (1-4) / high (5-7)
Factual knowledge about COVID-19 (a) (b)	low / high
Measures and behavior to avoid a SARS-CoV-2 infection	
Adherence to vaccination strategies is important	yes / no
Routine vaccination behavior is important	yes / no
Preventive Behavior in the last seven days	yes / no
Use of herbal supplements or homeopathies to prevent SARS-CoV-2 infection	yes / no
Use of antibiotics to prevent SARS-CoV-2 infection	yes / no

COVID-19 related impacts	
One of the parents lost his job during the pandemic	yes / no
One of the parents started working during the pandemic	yes / no
Family's economic situation during the pandemic	Same / increase / decrease
Health status worsened during the pandemic overall	No (It has improved or remained the same) Yes (it has worsened)
Mental health worsened during the pandemic overall	No (It has improved or remained the same) Yes (it has worsened)

* Adjustment variable for participants under 16 years old

(a) Question asked only for students over 16 years

(b) Composite indicator created to measure knowledge about COVID-19 among students over 16 years. Three aspects, groups at risk, symptoms and means of transmission were evaluated through 21 questions. A point was assigned to each question, which at the end were added to classify the participant.

Statistical analysis

A descriptive approach was carried out to present the vaccination status for all students and acceptability and reasons for refusal and hesitancy for parents of students under 16 years and students over 16 years. To describe the frequency of these variables, we present the data collected in October 2021 and January 2022. For the analysis, the student's data were aggregated in two groups, under 16 years (3-15 years), and over 16 years due to different methodology of data collection.

Each variable had between 10 and 30% missing throughout the sample, resulting in missed observations, so prior to analysis, we performed an imputation of multiple data sets by the chained equation method, obtaining 20 imputed datasets (26), that allowed proceed univariate and multivariate analyzes with the same participants. We compared the values of imputed and unimputed variables using a chi-square test on the first set of imputed data, for each variable. We repeat the description presented in tables 4 and 5, using the imputed dataset and, for univariate, we use the set of all imputed datasets. The univariate analysis was adjusted for a 3–15-year age group, using a binomial logistic regression, pooling the results through Rubin's Rules (RR). We calculated the Odds Ratio (OR) with 95% confidence interval (CI) and p-value, which we considered $p < 0.05$ statistically significant.

A multivariate analysis was performed only with the parents' database (students under 16 year) due to the low number of unvaccinated students over 16 years ($n=24$). We tested multicollinearity with a correlation matrix for each variable, excluding those with a correlation coefficient greater than 0.8 in absolute value.

In the multivariate model we proceed a Deletion Substitution Addition (DSA), with 50 iterations. DSA is an algorithm for Machine Learning that chooses the model

with the smallest Root Mean Square Error (RMSE). This method consists of adding, removing and replacing variables and performing a cross-validation in 5 rounds with 5 iterations, resampling the database in 5 random partitions where each model iterations is done in one partition and validated in the other 4, making that the model to be tested not only on the main sample but also on different subsamples. The DSA function was run in one imputed dataset, and a logistic regression was performed to all imputed datasets to keep only the significant variables, through a backward elimination. To ensure consistent results, the DSA model was used on the first and last imputed datasets, and on one more randomly selected dataset (dataset 11), and as a result, we obtained the same final model. The performance of the models was accessed by the Akaike Information Criterion (AIC), adjusted R-square, criteria that defined the choice for the DSA model.

We performed a McNemar test, which selects participants who were matched in the two samples (N=2,145), to see if there was significance between the difference in acceptability rates between October 2021 and January 2022 between parents and students.

All analyses were carried out with R (version 4.1.2). The imputation was proceeded by *mice* package and the Rubin's Rules by the *pool* function in the same package, in RStudio Software (27).

Ethics approval

This study was approved on 17 December 2020 by the Ethical Committee of the Foundation University Institute for Research in Primary Health Care Jordi Gol i Gurina (IDIAPJGol) (code 20/192-PCV). A written informed consent was obtained from school staff, and since it includes minors, was signed for parents or guardians of children under 16 years and by participants older than 16 years that signed by themselves. All documents were archived in a place accessed only by the researchers. The signed document provided information about, procedures, risks, use of the collected data, anonymity, confidentiality, and general information about the study. All participants were free to decline/withdraw consent at any time without providing a reason and without being subject to any resulting detriment.

Results

COVID-19 vaccination status and intentions

The vaccination coverage against SARS-CoV-2 in CSSNC was 36.1% for students under 16 years and 92.4% for students over 16 years in October 2021, increasing to 70.8% and 95.8% <16y-old and >16y-old, respectively, in January 2022. Among unvaccinated students over 16 years 28 (30.1%) and 15 (62.5%), in October and January respectively, refused to be vaccinated. The acceptability among their parents was proportionally higher among students aged 5-11 in October (70.2%) and students aged 3-4 in January (47.8%) but considering the denominators this result must be interpreted with caution, the parents' intention also varied significantly between October 2021 and January 2022, according to the McNemar test (Table 2).

Table 2 Vaccination against SARS-CoV-2 and intentions among unvaccinated students over 16 years and parents of unvaccinated students under 16 years at SSNC, Catalonia, Spain. October 2021 and January 2022.

	October 2021								January 2022							
	Age group (years)								Age group (years)							
	3-4		5-11		12-15		>16		3-4		5-11		12-15		>16	
	N=213	N=1085	N=860	N=1225					N=196	N=1035	N=834	N=570				
	n	%	n	%	n	%	n	%	N	%	n	%	n	%	n	%
Vaccination Status																
Unvaccinated	213	100%	1080	99.5%	88	10.2%	93	7.6%	184	93.9%	385	37.2%	33	4.0%	24	4.2%
Vaccinated	0	0%	5	0.5%	772	89.8%	1132	92.4%	12	6.1%	650	62.8%	801	96.0%	546	95.8%
Intentions among unvaccinated																
Accept	125	58.7%	756	70.2%	49	56.3%	38	40.9%	88	47.8%	161	41.8%	8	24.2%	5	20.8%
Hesitancy	71	33.3%	245	22.7%	26	29.9%	27	29.0%	67	36.4%	151	39.2%	9	27.3%	4	16.7%
Refusal	17	8.0%	76	7.1%	12	13.8%	28	30.1%	29	15.8%	73	19.0%	16	48.5%	15	62.5%

Reasons and determinants to hesitancy and refusal of COVID-19 vaccine

We investigated the reasons for hesitation or refusal among parents and students in this study. The 11 key reasons informed by parents in both endpoints, were quite similar, *concerning about side effects* (67.1% and 57.4% respectively); *insufficient research about vaccine safety and efficacy in children* (52.1% and 50.4% respectively) and *demand for more information to deciding to vaccinate their children* (53.5% and 34.5% respectively). For students, the key reasons to hesitancy or refusal were slightly different in the two periods. In October 2021 most unvaccinated students reported *concern with the time to development the vaccine* (63.6%), *concern about side effects* (50.9%) and *necessity for more information before deciding to vaccinate* (45.5%). In January 2022, the main reason was *concerning about side effects* (68.4%), *time to*

development the vaccine (63.2%) and previous COVID-19 disease (42.1%) (Fig. 1a and 1b).



Fig 1. Reported reasons to SARS-CoV-2 vaccine hesitancy or refusal among unvaccinated. Fig 1a for parents of unvaccinated students under 16 years and Fig 1b for students over 16 years. The N for parents was 447 in October 2021 and 55 in January 2022 and for students was 345 in October 2021 and 19 in January 2022. SSNC project, Catalonia, Spain. October 2021 and January 2022.

Students' descriptive and univariate analysis

The perception that it is easy to avoid a SARS-CoV-2 infection (OR 0.29 95%CI 0.09-0.88) and the use of herbal supplements and homeopathies to avoid a SARS-CoV-2 infection (OR 0.22 95%CI 0.08-0.63) were negatively associated with vaccine acceptance. A higher self-perceived knowledge (OR 3.6 95%CI 1.27-10.11) were positively associated with acceptability. As expected, adherence to vaccination strategies overall (OR 15.23 95%CI 5.13-45.19) and routine vaccination behavior (OR 5.49 95%CI 2.08-14.49) was strongly and positively associated with vaccine acceptability (Table 3).

Table 3. Descriptive and univariate analysis between sociodemographic, health status, perception, attitudes and knowledge, behavior, COVID-19 related impacts and vaccine acceptability among students over 16 years in SSNC. Catalonia, January 2022

Variables	Acceptability		Univariate analysis*		
	No N=19	Yes N=551	OR	CI95%	p-value
Sociodemographic					
Sex					
Female	14 (3.57%)	378 (96.4%)			ref
Male	5 (2.81%)	173 (97.2%)	1.28	0.45-3.61	0.639
Health					
Perception about current health status					
Bad	0 (0.00%)	30 (100%)	-	-	-
Good	19 (3.52%)	521 (96.5%)	-	-	-
Perception about your current mental health					
Bad	8 (4.88%)	156 (95.1%)			ref
Good	11 (2.71%)	395 (97.3%)	1.4	0.51-3.86	0.514
Have a chronic illness					
No	19 (3.76%)	486 (96.2%)	-	-	-
Yes	0 (0.00%)	65 (100%)	-	-	-
Previous COVID-19					
No or don't know	15 (3.38%)	429 (96.6%)			ref
Yes	4 (3.17%)	122 (96.8%)	0.87	0.27-2.82	0.822
Knowledge, perceptions, attitudes and practices					
Perceived risk to become infected with SARS-CoV-2					
Unlikely	18 (4.02%)	430 (96.0%)			ref
Very likely	1 (0.82%)	121 (99.2%)	3.93	0.51-29.96	0.188
Perceived severity if get infected with SARS-CoV-2					
Won't be very sick	17 (3.91%)	418 (96.1%)			ref
Will be very sick	2 (1.48%)	133 (98.5%)	1.96	0.43-8.92	0.384

Avoid a SARS-CoV-2 infection during the pandemic is**						
Difficult	6 (1.99%)	296 (98.0%)				ref
Easy	13 (4.85%)	255 (95.1%)	0.29	0.09-0.88		0.029
Avoid SARS-CoV-2 infection in children during the pandemic						
Difficult	12 (3.06%)	380 (96.9%)				ref
Easy	7 (3.93%)	171 (96.1%)	0.79	0.29-2.17		0.649
Avoided contact with vulnerable people						
No	6 (3.82%)	151 (96.2%)				ref
Yes	13 (3.15%)	400 (96.9%)	1.2	0.41-3.54		0.739
Self-perceived knowledge about COVID-19**						
Low	12 (5.58%)	203 (94.4%)				ref
High	7 (1.97%)	348 (98.0%)	3.58	1.27-10.11		0.017
Factual knowledge about COVID-19						
Low	7 (5.83%)	113 (94.2%)				ref
High	12 (2.67%)	438 (97.3%)	2.49	0.93-6.67		0.069
Measures and behavior to avoid a SARS-CoV-2 infection						
Adherence to vaccination strategies is important**						
No	14 (15.4%)	77 (84.6%)				ref
Yes	5 (1.04%)	474 (99.0%)	15.23	5.13-45.19		<0.001
Routine vaccination behavior is important**						
No	11 (9.73%)	102 (90.3%)				ref
Yes	8 (1.75%)	449 (98.2%)	5.49	2.08-14.49		0.001
Preventive behavior to prevent SARS-CoV-2 infection (in the last seven days)						
No	3 (7.89%)	35 (92.1%)				ref
Yes	16 (3.01%)	516 (97.0%)	2.88	0.78-10.53		0.111
Use of herbal supplements or homeopathies as a health measure to prevent SARS-CoV-2 infection**						
No	11 (2.23%)	483 (97.8%)				ref
Yes	8 (10.5%)	68 (89.5%)	0.22	0.08-0.63		0.004
Used antibiotics as a health measure to prevent SARS-CoV-2 infection						
No	16 (3.43%)	450 (96.6%)				ref
Yes	3 (2.88%)	101 (97.1%)	0.97	0.27-3.39		0.956

* Univariate analysis adjusted by age for a 3–15-year age group, using a binomial logistic regression with all 20 imputed datasets, pooling the results through Rubin's Rules (RR).

** Significant variables ($p < 0.050$)

Parents' descriptive, univariate and multivariate analysis

A negative association was found between COVID-19 vaccine acceptability and birthplace, when at least one of the parents was born outside Spain (OR 0.63 95%CI 0.46-0.86), houses with more than five people living together (OR 0.7 95%CI 0.49-0.99), decrease of family's economic situation during the pandemic (OR 0.65 95%CI 0.47-0.9), use of herbal supplement or homeopathy as a measure to prevent a SARS-CoV-2 infection (OR 0.44 95%CI 0.29 -0.67), concern about spending too much time with family (OR 0.53 95%CI 0.29 -0.97) (Table 4).

A positive association was found between COVID-19 vaccine acceptability and when father (OR 2.45 95%CI 1.46-4.1) or mother (OR 1.68 95%CI 1.14-2.47) were employed, living with a healthcare work (OR 1.52 95%CI 1.03-2.25), a good perception about their current health status (OR 4.68 95%CI 1.16-18.84) and, adherence to vaccination strategies (OR 18.8 95%CI 6.93-50.98) and vaccination routine behavior (OR 2.7 95%CI 1.08-6.75) (Table 4).

Table 4. Descriptive and univariate analysis between sociodemographic, health status, perception, attitudes and knowledge, behavior, COVID-19 related impacts and vaccine acceptability among parents of students under 16 years in SSNC. Catalonia, January 2022.

Variables	Acceptability		Univariate analysis*		
	No N=345	Yes N=1720	OR	CI95%	P-value
Sociodemographic					
Student age group					
3-5	132 (43.3%)	173 (56.7%)			
6-11	188 (20.3%)	738 (79.7%)			
12-15	25 (3.00%)	809 (97.0%)			
Sex					
Female	187 (17.5%)	883 (82.5%)			ref
Male	158 (15.9%)	837 (84.1%)	1.1 4	0.89-1.46	0.297
Students' immigration status (birthplace)					
Spain	331 (16.6%)	1663 (83.4%)			
Another country	14 (19.7%)	57 (80.3%)	0.6 5	0.34-1.25	0.199
Parents immigration status (birthplace)**					

Spain	273 (15.8%)	1457 (84.2%)				ref
Another country	72 (21.5%)	263 (78.5%)	0.6 3	0.46-0.86		0.004
Father employment situation **						
Unemployed, retired or lay-of	33 (30.6%)	75 (69.4%)				ref
Employed	312 (15.9%)	1645 (84.1%)	2.4 5	1.46-4.1		0.001
Mother employment situation **						
Unemployed, retired or lay-of	64 (23.4%)	210 (76.6%)				ref
Employed	281 (15.7%)	1510 (84.3%)	1.6 8	1.14-2.47		0.009
Father educational level						
None or primary school	40 (12.0%)	292 (88.0%)				ref
secondary school	150 (19.2%)	631 (80.8%)	0.7 5	0.47-1.19		0.217
University	155 (16.3%)	797 (83.7%)	1.0 6	0.66-1.72		0.803
Mother educational level						
None or primary school	26 (15.4%)	143 (84.6%)				ref
secondary school	112 (17.9%)	513 (82.1%)	0.8 3	0.46-1.49		0.527
University	207 (16.3%)	1064 (83.7%)	1.1	0.64-1.88		0.736
House size (in meters)						
<70m2	62 (21.7%)	224 (78.3%)				ref
>70m2	283 (15.9%)	1496 (84.1%)	1.1	0.77-1.58		0.603
Number of people living in the same residence**						
1-4	273 (16.1%)	1426 (83.9%)				ref
5-9	72 (19.7%)	294 (80.3%)	0.7	0.49-0.99		0.046
Live with small/underage children						
No	105 (16.1%)	546 (83.9%)				ref
Yes	240 (17.0%)	1174 (83.0%)	1.1	0.82-1.47		0.539
Living with people over 65 years						
No	330 (16.6%)	1652 (83.4%)				ref
Yes	15 (18.1%)	68 (81.9%)	1.0 9	0.52-2.28		0.817
Live with a health care worker (HCW)**						
No	292 (17.2%)	1403 (82.8%)				ref
Yes	53 (14.3%)	317 (85.7%)	1.5 2	1.03-2.25		0.036

Health status

Perception about current health status **

Bad	5 (35.7%) 340	9 (64.3%) 1711	4.6	1.16-	ref
Good	(16.6%)	(83.4%)	8	18.84	0.031

Perception about current mental health status

Bad	9 (14.3%) 336	54 (85.7%) 1666	2.2		ref
Good	(16.8%)	(83.2%)	6	0.94-5.42	0.069

Have a chronic illness

No	324 (16.8%)	1610 (83.2%)			ref
Yes	21 (16.0%)	110 (84.0%)	0.7	0.43-1.35	0.344

Previous COVID

No or don't know	289 (16.1%)	1510 (83.9%)			ref
Yes	56 (21.1%)	210 (78.9%)	0.6	0.47-1.01	0.058

Perceptions, attitudes and practices

Perceived risk to become infected with SARS-CoV-2

Unlikely	279 (16.3%)	1437 (83.7%)			ref
Very likely	66 (18.9%)	283 (81.1%)	1.0	0.7-1.48	0.91

Perceived severity if get infected with SARS-CoV-2

Won't be very sick	296 (17.0%)	1448 (83.0%)			ref
Will be very sick	49 (15.3%)	272 (84.7%)	1.0	0.72-1.61	0.705

Avoid SARS-CoV-2 infection in children during the pandemic

Difficult	283 (17.0%)	1377 (83.0%)			ref
Easy	62 (15.3%)	343 (84.7%)	0.9	0.67-1.35	0.765

Avoided contact with vulnerable people

No	92 (21.8%) 253	330 (78.2%) 1390			ref
Yes	(15.4%)	(84.6%)	1.3	0.95-1.79	0.099

Measures and behavior to avoid a SARS-CoV-2 infection

Adherence to vaccination strategies is important**

No	23 (57.5%) 322	17 (42.5%) 1703	18.	6.93-	ref
Yes	(15.9%)	(84.1%)	8	50.98	<0.001

Routine vaccination behavior is important

No	9 (21.4%)	33 (78.6%)				ref
Yes	336 (16.6%)	1687 (83.4%)	2.7	1.08-6.75	0.034	
Preventive behavior to prevent SARS-CoV-2 infection						
No	0 (0.00%)	15 (100%)	*	*	*	
Yes	345 (16.8%)	1705 (83.2%)	*	*	*	
Use of herbal supplements or homeopathies as a health measure to prevent SARS-CoV-2 infection**						
No	288 (15.3%)	1589 (84.7%)				ref
Yes	57 (30.3%)	131 (69.7%)	0.4	0.29-0.67	<0.001	
Used antibiotics as a health measure to prevent SARS-CoV-2 infection						
No	329 (16.6%)	1655 (83.4%)				ref
Yes	16 (19.8%)	65 (80.2%)	0.7	0.36-1.4	0.319	
COVID-19 related impacts						
One of the parents lost his job during the pandemic**						
No	324 (16.3%)	1664 (83.7%)				ref
Yes	21 (27.3%)	56 (72.7%)	0.5	0.29-0.97	0.038	
One of the parents started working during the pandemic						
No	334 (16.5%)	1694 (83.5%)				ref
Yes	11 (29.7%)	26 (70.3%)	0.6	0.25-1.45	0.258	
Family's economic situation during the pandemic**						
Same	246 (15.2%)	1375 (84.8%)				ref
Decrease	85 (21.4%)	313 (78.6%)	0.6	0.47-0.9	0.01	
Increase	14 (30.4%)	32 (69.6%)	0.6	0.31-1.4	0.273	
Health status worsened during the pandemic						
No	339 (16.8%)	1674 (83.2%)				ref
Yes	6 (11.5%)	46 (88.5%)	1.0	0.4-2.63	0.954	
Mental health worsened during the pandemic						
No	321 (16.8%)	1589 (83.2%)				ref
Yes	24 (15.5%)	131 (84.5%)	0.6	0.36-1.08	0.091	

* Univariate analysis adjusted by age for a 3–15-year age group, using a binomial logistic regression with all 20 imputed datasets, pooling the results through Rubin’s Rules (RR).

** Significant variables (p<0.050)

In multivariate analyses, the variables associated with vaccine acceptability were age, adherence to previous vaccination, father work situation, influence of health care workers. Variables associated with refusal or hesitancy was use of herbal supplements and homeopathies (Table 5).

Table 5. Multivariate analysis between sociodemographic, perceptions, attitudes, behavior and knowledge indicators among parents of under 16 years students, in SSNC. Catalonia, January 2022.

Variable	Multivariate analysis*		
	OR	95%CI	p-value
Age group 6-11 years	3.39	2.53-4.53	<0.001
Age group 12-15 years	31.39	18.98-51.92	<0.001
Adherence to vaccination campaigns and strategies	17.92	6.57-48.87	<0.001
Use of herbal supplements or homeopathies	0.47	0.31-0.74	0.001
Father working status: employed	2.42	1.42-4.12	0.001
Living with health care worker (HCW)	1.51	1-2.27	0.051

* Multivariate analysis by a Deletion Substitution Addition (DSA) machine learning algorithm with 50 iterations. The performance of the models was accessed by the Akaike Information Criterion (AIC), adjusted R-square, criteria that defined the choice for the DSA model.

The AIC for the DSA model was 1504.17 (SD=11.47), mean of the 20 imputed data sets, and the adjusted mean R-square was 0.2 (SD=0.006), which corresponds to the variability of the R-square obtained by the models of each of the imputed data sets, and suggests that similar results were obtained across all imputed datasets and may be an indicator of a high-quality imputation process.

Discussion

Our study found the COVID-19 vaccine acceptability was high among adolescents (96.7%) and parents (83.3%). The main reason to refusal and hesitancy reported by parents was concern about side effects, safety and lack of information, all variables associated. On the other hand, variables with impact in the vaccine acceptability were, students age, compliance of routine vaccination, work situation, use of alternative practices as homeopathy, perception about current health, and COVID-19 related impacts.

The prevalence of COVID-19 vaccine hesitancy in Spain was estimated at 6.2%, the lowest according to a study with unvaccinated participants from eight European countries, proceeded in June 2021, and the main determinants are gender, age, education and employment (11). A meta-analysis estimates the prevalence of COVID-19 vaccine hesitancy at 25% globally, recommending interventions among women, people with low educational levels, unemployed, people living in households with five or more individuals, and those who no trust in the COVID-19 safety (5).

A review found a global average for COVID-19 vaccine acceptance of 61.4%, with significantly difference between countries, varying between 42.9% in Saudi Arabia and 91.4% in Brazil (17), while the overall Europe acceptance was 72.6% (11). Another study found that in United States 49% of parents were agreeing to vaccinate their children and 44% are planning to vaccinate them when the vaccine become available (28). In Saudi Arabia, 47.6% of parents were ready to vaccinate their children (29), in Turkey, 36% of parents were willing to their children receive the vaccine (30), however 66% of parents were hesitant about a foreign vaccine and 37.4% were hesitant with a domestic vaccine (31).

In this study, the highest rates of refusal of the COVID-19 vaccine were among parents of students aged 3 to 4 years (41-49%), however, at the time of the study, there was still no vaccine approved for this population. For the 5-11 group, the vaccine had been approved during the first round of data collection, and although we found 30-22% refusal, we also found a significant increase in vaccine coverage (0-63%) immediately after approval of the vaccine for this age group. Similar behavior in relation to vaccine refusal rates was observed (32), where besides the data collection about vaccination have been carried out in the recent approval context, the vaccination schedule was just starting, and the services were still organizing for this demand. The contradictory arguments about the risk-benefit and severity of infection in this age group probably also contributed to this hesitation. Finally, we found that parents or guardians of older children were more likely to allow their vaccination, a result similar was found in another study (23).

The main reason to refusal and hesitancy reported by parents was concern about side effects, safety and lack of information, all variables associated. Variables with impact in the vaccine acceptability were, students age, compliance of routine vaccination, work situation, use of alternative practices as homeopathy, perception about current health, and COVID-19 related impacts.

Socioeconomic characteristics can be an obstacle to vaccination strategies, even considering the free vaccine (3,33), for example, in our study we found that being employed was associated with a higher probability of accepting the vaccination of their children, while a greater number of people living in the same household, a decrease in the family's economic situation during the pandemic was associated with a lower probability to vaccinate their children. Social determinants and characteristics related to less access to health policies and information had a greater impact on vaccine acceptability, a result also observed in different studies on coverage and acceptability among low-, middle- and high-income countries (4,34). Moreover, it is known that the burden of COVID-19 has affected different socioeconomic groups with different intensity, as observed in this populational study about mortality associated with socioeconomic status in Barcelona, Spain (35).

The parents' migratory situation, when at least one was born abroad but lives in Spain, was associated with vaccine hesitancy, a similar result was founded in a Canadian study (18). Disparities in vaccination rates among students of different ethnicities was also demonstrated previously (15).

As expected, parents who live with health professionals were more likely to vaccinate their children. This result reinforces the important role of health care professionals on vaccine promotion strategies. Vaccine hesitancy among health professionals, can be a very important problem to public health strategies and, in this case, for vaccine acceptance, since trust in public health authorities can be an important influence on the decision to vaccinate or vaccinate persons in their care (3,36), as well as the message that reinforces safety and efficacy, disseminated by health professionals when vaccinating, can be useful to minimize vaccine hesitancy and refusal (34). Also, they are a high-risk group for exposure to SARS-CoV-2 and had an understandable role in the transmission of the virus, for this reason, HCW were a priority group eligible for vaccination as soon as possible (36,37).

Parents who had perceived their children are healthy were more likely to allow them to be vaccinated, the same result was observed in a study with health professionals (38). The history of receiving previous vaccine for another diseases among parents and students had increases the likely to be vaccinated and allow vaccinated their children, also, parents and adolescents who were previous vaccinated had more likely to accept the COVID-19 vaccine, findings consistent with another previous studies (38–43).

Use of alternative medicines such as homeopathy, that had a negative association with vaccine acceptability among both, parents and adolescents. This can be related to the lower use of health services and distrust of pharmacological therapies by these users. In addition, personal beliefs were already associated with vaccine refusal among parents in previous studies (44). A Spanish study found a lower demand for influenza vaccination among homeopathy users, that rejects the vaccine for themselves and for their children (45). Moreover, family uptake behavior, can affect vaccine uptake among adolescents, as indicated in previous studies(39).

For unvaccinated students, the main reasons to vaccine refusal or hesitancy were concern about side effects, safety and vaccine distrust, agreeing with other studies in similar populations that demonstrated the significance of these variables in the decision not to be vaccinated (40,41). The associated variables among students were risk perception, knowledge, alternative medical practices as homeopathy and compliance of routine vaccination. Students with higher perceived knowledge about COVID-19 were more likely to accept the vaccine, that is coherent with the discussion about access to adequate health information as an important predictor to vaccine acceptability (46–48).

Students that belief is easy to avoid a SARS-COV-2 infection, that is, who do not perceive the risk to be infected were more likely to refuse the vaccine against COVID-19, consistent with other studies (40,49).

A previous SARS-CoV-2 infection as a reason for vaccine refusal or hesitation increased between October 2021 and January 2022 among the participants may be related with the large wave caused by the Omicron variant in Catalonia, occurred in early December 2021, between the two points of the study data collection. The higher transmissibility and increasing infections, in fully vaccinated people included, could be associated with untrust and doubts about the vaccine effectiveness increasing the hesitation. Moreover, unlike the beginning of the pandemic, the perception of risk has changed, and people believe that COVID-19 has become a mild disease now.

Vaccine access is an important goal for health policies. It is very important understand how the lack of information, personal beliefs, limited health literacy and lower risk awareness was associated with vaccine refusal and hesitancy as discussed by another research (40). Previous study showed that recommendation for the Government has

strongly associated with acceptance (48), and especially when qualified information is available (23,29,44,50,51).

Limitations

Although the study design was adequate for the purpose of the study, the results should be extrapolated with caution. Predictive capacity of the statistical models applied in this study are considerable high, but, despite the high prevalence of COVID-19 vaccine acceptability in our sample, the study population does not represent the overall children and parents of the country.

The sample heterogeneity allows to generate several hypotheses, these would eventually need to be confirmed with population-based surveys. The reported vaccine acceptability may not reflect actual vaccination behavior as well. The fact that vaccination intentions were only asked for those who were not yet vaccinated, have also reduced this population size over time. Therefore, new research, especially longitudinal studies at different intervals, will be needed to investigate and evaluate this behavior in different periods of COVID-19 vaccination strategies.

Conclusions

This is the first investigation into COVID-19 vaccine hesitancy among parents and adolescents in Catalonia, Spain. Precaution regarding parental vaccination of children is consistently present across different periods of the pandemic, suggesting that individual risk-benefit continues to guide decision-making processes regarding vaccination.

Findings on the impact of social and structural factors on COVID-19 vaccine acceptability highlight the importance of specifically targeted interventions to address frequent misunderstandings and reinforce the common benefit of vaccination at the population level.

The evolving nature of SARS-CoV-2 and the potential role of vaccines in the pediatric population are still full of uncertainties. Both understanding the biological evolution of the virus and the persistence of natural and acquired immune protection will be crucial in defining vaccine recommendations for children.

Finally, the emergency response to SARS-CoV-2 needs to leave us a legacy of a health system prepared for increasingly efficient responses to future threats to public health. In this context, monitoring compliance and evolution of preventive public health measures, such as vaccine hesitancy has been important to better understand the interaction between different multilevel determinants and its maintenance over time will be necessary to correctly delineate future interventions.

Conflict of interest

"The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. This does not alter our adherence to PLOS ONE policies on sharing data and materials."

Author contributions

JC and CF conceived and designed the study. AC and AB were responsible for the data collection; LA were responsible for the data. FG and LA performed the statistical and epidemiological analysis. FG wrote the first draft of the manuscript and AS contributed with the final draft. All authors drafted the manuscript for important intellectual content, contributed to revision of the final version of the manuscript, approved the final version submitted, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. JC acts as guarantor. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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Data sharing

All anonymized databases and their corresponding codebooks are available in the public repository <https://github.com/Escoles-Sentinella/Acceptability-of-COVID-19-vaccine>. Due to legal restrictions in relation to the “Personal Information Protection Act,” personal or spatial data that allow identified any participant, including the name of the school, which was used as an adjustment factor in the analysis, cannot be made publicly available. Requests for complementary data can be sent as a formal proposal to the CEEISCAT via email ceeiscat@iconcologia.net.

References

1. Viveiros-Rosa SG, Mendes CDS, Farfán-Cano GG, El-Shazly M. The race for clinical trials on Omicron-based COVID-19 vaccine candidates: Updates from global databases. *Narra J.* 2022 Nov 6;2(3):e88.
2. Dhama K, Nainu F, Frediansyah A, Yatoo MohdI, Mohapatra RK, Chakraborty S, et al. Global emerging Omicron variant of SARS-CoV-2: Impacts, challenges and strategies. *J Infect Public Health.* 2023 Jan;16(1):4–14.
3. Viswanath K, Bekalu M, Dhawan D, Pinnamaneni R, Lang J, McLoud R. Individual and social determinants of COVID-19 vaccine uptake. *BMC Public Health.* 2021 Dec 1;21(1).

4. Yamey G, Garcia P, Hassan F, Mao W, McDade KK, Pai M, et al. It is not too late to achieve global covid-19 vaccine equity. *BMJ*. 2022 Mar 24;e070650.
5. Fajar JK, Sallam M, Soegiarto G, Sugiri YJ, Anshory M, Wulandari L, et al. Global Prevalence and Potential Influencing Factors of COVID-19 Vaccination Hesitancy: A Meta-Analysis. Vol. 10, *Vaccines*. MDPI; 2022.
6. España, Ministerio de Sanidad, Grupo de trabajo técnico de vacunación COVID-19. Estrategia de vacunación frente a COVID19 en España - Actualización 2 [Internet]. 2021 [cited 2022 Feb 1]. Available from: <https://www.sanidad.gob.es/profesionales/saludPublica/ccayes/alertasActual/nCov/vacunaCovid19.htm>
7. European Medicines Agency. Comirnaty COVID-19 vaccine: EMA recommends approval for children aged 5 to 11 [Internet]. Web. 2021 [cited 2022 Feb 1]. Available from: <https://www.ema.europa.eu/en/news/comirnaty-covid-19-vaccine-ema-recommends-approval-children-aged-5-11>
8. Generalitat de Catalunya. Dades obertes i COVID-19 [Internet]. <https://governobert.gencat.cat>. 2022 [cited 2022 Apr 27]. Available from: https://governobert.gencat.cat/es/dades_obertes/dades-obertes-covid-19/
9. WHO. REPORT OF THE SAGE WORKING GROUP ON VACCINE HESITANCY. 2014.
10. Voysey M, Clemens SAC, Madhi SA, Weckx LY, Folegatti PM, Aley PK, et al. Safety and efficacy of the ChAdOx1 nCoV-19 vaccine (AZD1222) against SARS-CoV-2: an interim analysis of four randomised controlled trials in Brazil, South Africa, and the UK. *The Lancet*. 2021 Jan;397(10269):99–111.
11. Steinert JI, Sternberg H, Prince H, Fasolo B, Galizzi MM, Bütthe T, et al. COVID-19 vaccine hesitancy in eight European countries: Prevalence, determinants, and heterogeneity. *Sci Adv* [Internet]. 2022 Apr 1 [cited 2022 Jul 1];8(17):9825. Available from: <https://www.science.org>
12. Olusanya OA, Bednarczyk RA, Davis RL, Shaban-Nejad A, Moschese V, Martire B, et al. Addressing Parental Vaccine Hesitancy and Other Barriers to Childhood/Adolescent Vaccination Uptake During the Coronavirus (COVID-19) Pandemic. Article [Internet]. 2021;12:1. Available from: www.frontiersin.org

13. Hassan W, Kazmi SK, Tahir MJ, Ullah I, Royan HA, Fahriani M, et al. Global acceptance and hesitancy of COVID-19 vaccination: A narrative review. *Narra J.* 2021 Dec 1;1(3).
14. Rosiello DF, Anwar S, Yufika A, Adam RY, Ismaeil MIH, Ismail AY, et al. Acceptance of COVID-19 vaccination at different hypothetical efficacy and safety levels in ten countries in Asia, Africa, and South America. *Narra J.* 2021 Dec 1;1(3).
15. Gurley S, Bennett B, Sullivan P, Kiley M, Linde J, Szczerbacki D, et al. COVID-19 Vaccine Perceptions, Intentions, and Uptake: A Prospective College-based Cohort Study (Preprint). *JMIR Public Health Surveill.* 2021 Dec 15;
16. Sallam M. Covid-19 vaccine hesitancy worldwide: A concise systematic review of vaccine acceptance rates. *Vaccines (Basel).* 2021 Feb 1;9(2):1–15.
17. Chen F, He Y, Shi Y. Parents' and Guardians' Willingness to Vaccinate Their Children against COVID-19: A Systematic Review and Meta-Analysis. Vol. 10, *Vaccines.* MDPI; 2022.
18. Nazeem Muhajarine, Adeyinka DA, Mccutcheon J, Green KL, Id MF, Kallio Id N. COVID-19 vaccine hesitancy and refusal and associated factors in an adult population in Saskatchewan, Canada: Evidence from predictive modelling. 2021; Available from: <https://doi.org/10.1371/journal.pone.0259513>
19. Toubiana J, Poirault C, Corsia A, Bajolle F, Fourgeaud J, Angoulvant F, et al. Kawasaki-like multisystem inflammatory syndrome in children during the covid-19 pandemic in Paris, France: prospective observational study. 2020; Available from: <http://dx.doi.org/10.1136>
20. Feldstein LR, Tenforde MW, Friedman KG, Newhams M, Rose EB, Dapul H, et al. Characteristics and Outcomes of US Children and Adolescents With Multisystem Inflammatory Syndrome in Children (MIS-C) Compared With Severe Acute COVID-19 Supplemental content. *JAMA [Internet].* 2021;325(11):1074–87. Available from: <https://jamanetwork.com/>
21. Luxi N, Giovanazzi A, Capuano A, Crisafulli · Salvatore, Paola ·, Cutroneo M, et al. COVID-19 Vaccination in Pregnancy, Paediatrics, Immunocompromised Patients, and Persons with History of Allergy or Prior SARS-CoV-2 Infection: Overview of Current Recommendations and Pre-and Post-Marketing Evidence for Vaccine Efficacy and

- Safety Key Points. 2021;44:1247–69. Available from: <https://doi.org/10.1007/s40264-021-01131-6>
22. Igor Rudan, Davies Adeloye, Vittal Katikireddi, Josie Murray, Colin Simpson, Syed Ahmar Shah, et al. The COVID-19 pandemic in children and young people during 2020-2021: A complex discussion on vaccination. *J Glob Health*. 2021;11.
 23. Zychlinsky Scharff A, Paulsen M, Schaefer P, Tanisik F, Sugianto RI, Stanislawski N, et al. Students' age and parental level of education influence COVID-19 vaccination hesitancy. *Eur J Pediatr*. 2022 Apr 1;181(4):1757–62.
 24. Bordas A, Soriano-Arandes A, Subirana M, Malagrida R, Reyes-Urueña JM, Folch C, et al. Study protocol for monitoring SARS-CoV-2 infection and its determinants in Catalonia (Spain): an observational and participatory research approach in a Sentinel Network of Schools. *BMJ Open*. 2022 Jan 25;12(1):e055649.
 25. Betsch C, Wieler LH, Habersaat K. Monitoring behavioural insights related to COVID-19. *The Lancet*. 2020 Apr;395(10232):1255–6.
 26. White IR, Royston P, Wood AM. Multiple imputation using chained equations: Issues and guidance for practice. *Stat Med*. 2011 Feb 20;30(4):377–99.
 27. Buuren S van, Groothuis-Oudshoorn K. MICE: Multivariate Imputation by Chained Equations in R. *J Stat Softw*. 2011;45(3).
 28. Ruggiero KM, Wong J, Fryer Sweeney C, Avola A, Auger A, Macaluso M, et al. Parents' Intentions to Vaccinate Their Children Against COVID-19. 2021 [cited 2022 Jul 1]; Available from: <https://doi.org/10.1016/j.pedhc.2021.04.005>
 29. Temsah MH, Alhuzaimi AN, Aljamaan F, Bahkali F, Al-Eyadhy A, Alrabiaah A, et al. Parental Attitudes and Hesitancy About COVID-19 vs. Routine Childhood Vaccinations: A National Survey. *Front Public Health*. 2021 Oct 13;9.
 30. Yilmaz M, Sahin MK. Parents' willingness and attitudes concerning the COVID-19 vaccine: A cross-sectional study. *Int J Clin Pract*. 2021 Sep 29;75(9).
 31. Yigit M, Ozkaya-Parlakay A, Senel E. Evaluation of COVID-19 Vaccine Refusal in Parents. *Pediatric Infectious Disease Journal*. 2021 Apr 4;40(4):e134–6.

32. Alfieri NL, Kusma JD, Heard-Garris N, Davis MM, Golbeck E, Barrera L, et al. Parental COVID-19 vaccine hesitancy for children: vulnerability in an urban hotspot. *BMC Public Health* [Internet]. 2021 [cited 2022 Jul 1];21(1662). Available from: <https://doi.org/10.1186/s12889-021-11725-5>
33. Nguyen KH, Nguyen K, Corlin L, Allen JD, Chung M. Changes in COVID-19 vaccination receipt and intention to vaccinate by socioeconomic characteristics and geographic area, United States, January 6–March 29, 2021. *Ann Med*. 2021;53(1):1419–28.
34. Solís Arce JS, Warren SS, Meriggi NF, Scacco A, McMurry N, Voors M, et al. COVID-19 vaccine acceptance and hesitancy in low- and middle-income countries. *Nat Med*. 2021 Aug 16;27(8):1385–94.
35. Julieta Politi, Mario Martín-Sánchez, Lilas Mercuriali, Blanca Borrás-Bermejo, Joaquín Lopez-Contreras, Anna Vilella, et al. Epidemiological characteristics and outcomes of COVID-19 cases: mortality inequalities by socioeconomic status, Barcelona, Spain, 24 February to 4 May 2020. *Eurosurveillance*. 2021 Sep 21;26(20).
36. ECDC. Facilitating COVID-19 vaccination acceptance and uptake in the EU/EEA Scope and purpose Target audience. 2021;
37. Pacella-LaBarbara ML, Park YL, Patterson PD, Doshi A, Guyette MK, Wong AH, et al. COVID-19 Vaccine Uptake and Intent Among Emergency Healthcare Workers: A Cross-Sectional Survey. *J Occup Environ Med*. 2021 Oct 1;63(10):852–6.
38. Rikitu Terefa D, Shama AT, Feyisa BR, Ewunetu Desisa A, Geta ET, Chego Cheme M, et al. COVID-19 Vaccine Uptake and Associated Factors Among Health Professionals in Ethiopia. *Infect Drug Resist* [Internet]. 2021 Dec;Volume 14:5531–41. Available from: <https://www.dovepress.com/covid-19-vaccine-uptake-and-associated-factors-among-health-profession-peer-reviewed-fulltext-article-IDR>
39. Gray A, Fisher CB. Determinants of COVID-19 Vaccine Uptake in Adolescents 12–17 Years Old: Examining Pediatric Vaccine Hesitancy Among Racially Diverse Parents in the United States. *Front Public Health*. 2022 Mar 22;10.
40. Rehati P, Amaerjiang N, Yang L, Xiao H, Li M, Zunong J, et al. COVID-19 Vaccine Hesitancy among Adolescents: Cross-Sectional School Survey in Four Chinese Cities Prior to Vaccine Availability. *Vaccines (Basel)*. 2022 Mar 15;10(3):452.

41. Sethi S, Kumar A, Mandal A, Shaikh M, Hall CA, Kirk JMW, et al. The UPTAKE study: a cross-sectional survey examining the insights and beliefs of the UK population on COVID-19 vaccine uptake and hesitancy. *BMJ Open* [Internet]. 2021;11:48856. Available from: <http://dx.doi.org/10.1136/bmjopen-2021-048856>
42. Alhazza SF, Altalhi AM, Alamri KM, Alenazi SS, Alqarni BA, Almohaya AM. Parents' Hesitancy to Vaccinate Their Children Against COVID-19, a Country-Wide Survey. *Front Public Health*. 2022 Apr 28;10.
43. Ng DLC, Gan GG, Chai CS, Anuar NAB, Sindeh W, Chua WJ, et al. The willingness of parents to vaccinate their children younger than 12 years against COVID-19: a cross-sectional study in Malaysia. *BMC Public Health*. 2022 Dec 29;22(1):1265.
44. McKee C, Bohannon K. Exploring the Reasons Behind Parental Refusal of Vaccines. *The Journal of Pediatric Pharmacology and Therapeutics*. 2016 Apr 1;21(2):104–9.
45. Pinilla J, Rodriguez-Caro A. Differences in healthcare utilisation between users and non-users of homeopathic products in Spain: Results from three waves of the National Health Survey (2011-2017). *PLoS One*. 2019 May 13;14(5):e0216707.
46. Islam MdS, Siddique AB, Akter R, Tasnim R, Sujan MdSH, Ward PR, et al. Knowledge, attitudes and perceptions towards COVID-19 vaccinations: a cross-sectional community survey in Bangladesh. *BMC Public Health*. 2021 Dec 13;21(1):1851.
47. Adane M, Ademas A, Kloos H. Knowledge, attitudes, and perceptions of COVID-19 vaccine and refusal to receive COVID-19 vaccine among healthcare workers in northeastern Ethiopia. *BMC Public Health*. 2022 Dec 18;22(1):128.
48. Wong MCS, Wong ELY, Huang J, Cheung AWL, Law K, Chong MKC, et al. Acceptance of the COVID-19 vaccine based on the health belief model: A population-based survey in Hong Kong. *Vaccine*. 2021 Feb;39(7):1148–56.
49. Hilverda F, Vollmann M. The Role of Risk Perception in Students' COVID-19 Vaccine Uptake: A Longitudinal Study. 2021; Available from: <https://doi.org/10.3390/vaccines10010022>
50. Cordina M, Lauri MA, Lauri J. Attitudes towards COVID-19 vaccination, vaccine hesitancy and intention to take the vaccine. *Pharm Pract (Granada)*. 2021 Mar 21;19(1):2317.

51. Szilagyi PG, Shah MD, Delgado JR, Thomas K, Vizueta N, Cui Y, et al. Parents' Intentions and Perceptions About COVID-19 Vaccination for Their Children: Results From a National Survey. *Pediatrics*. 2021 Oct 1;148(4).

ARTICLE 3

Impact of the COVID-19 pandemic on the psychological well-being of adolescents by gender identity

SUMMARY

Objective of the study: This study aims to describe the impact of the COVID-19 pandemic on the emotional wellbeing of students over 15 in Catalan sentinel schools according to gender, to compare coping strategies adopted to manage the health crisis by gender and to show the relation between the strategies adopted and a worsening of mental health due to the COVID-19 pandemic.

Study design: Cross-sectional study in 16 secondary educational centres in Catalonia (academic year 2021-2022) that form part of the CSSNC Project.

Study population: For the objectives of this study, students over 15 years were selected.

Data collection: Data collection took place from October to December 2021 through an online questionnaire available in Catalan, Spanish and English

Variables, outcome and case definitions: The questionnaire included sociodemographic variables, self-perceived physical and/or mental health status, self-perceived impact of the pandemic on mental health, level of stress caused by uncertainty about the future generated by COVID-19, emotions felt in the last 7 days caused by the pandemic, level of concern about the impact of the pandemic on different aspects of life in relation to the last 7 days and strategies used to cope with the pandemic.

Data analysis: A descriptive analysis of the variables was carried out and differences between proportions according to gender were compared using the Chi-Square test, or the exact Fisher's exact test if observed cases were less than 5, and differences between means using the Student's T-Test. Logistic regression models were built to evaluate the association between coping strategies with self-perceived impact of the pandemic on the state of mental health, adjusting by gender, house size and type of educational centre (low, medium low, medium high and high complexity). Adjusted OR (ORa) were calculated with a Confidence Interval of 95% (IC95%).

Results: The main socio-demographic and health status characteristics by gender are presented in Table 1. The mean age of participating boys and girls was 16.9 and 16.8 years old respectively, most were born in Spain (89.9% girls and 93.0% boys) and 9.3% of girls and 8.5% of boys, respectively, reported a drop in family income since the start of the pandemic.

Boys presented a better self-perceived general health status compared to girls (95.3% good, very good or excellent for boys and 92.3% for girls) and also better mental health (87.3% good, very good or excellent for boys and 63.8% for girls). Additionally, the percentage diagnosed with anxiety before or after the pandemic started was higher in girls (20.6% girls, 7.3% boys). A greater proportion of girls perceived a worsening in mental health due to the COVID-19 pandemic compared to boys (36.9% and 17.8%, respectively), while 5.7% of girls and 15.0% of boys perceived their mental health improved in this same period ($p < 0.001$). Additionally, the level of stress caused by uncertainty about the future generated for COVID-19 was also greater in girls than in boys ($M = 4.1$ [SD:1.7] and $M = 3.1$ [SD:1.8], respectively).

For all the emotions that can generate emotional discomfort evaluated, girls had statistically significant higher mean scores than boys, except for worry. The main emotions reported for both girls and boys were worried ($M = 2.7$ [SD:1.1] and $M = 2.2$ [SD:1.1], respectively) and boredom ($M = 2.7$ [SD:1.3] and $M = 2.4$ [SD:1.2], respectively), followed by frustration in girls ($M = 2.5$ [SD:1.3]) and disappointment in boys ($M = 1.9$ [SD:1.1]).

Regarding the level of concern (a lot/a great deal) about the impact of the pandemic on different aspects of life in the prior 7 days, most of the participants reported a high negative impact caused by the fact that friends and/or family could die (61.3% girls and 41.4% boys) and/or get sick (54.9% girls and 33.5% boys), together with the fear of losing jobs (themselves or family members) (46.5% girls and 29.6% boys).

One of the most frequent coping strategies was contact with friends online and/or social media (76.5% and 68.6% in boys and girls respectively), and other solitary digital activities like watching TV and/or films (80.8% and 69.7% in girls and boys respectively), both declared in a higher proportion by girls than boys. More than half the adolescents also referred to self-care strategies like taking exercise (59.7% and 63.2% in girls and boys, respectively), and/or other individual non-digital activities such as reading and/or writing (41.2% for girls and 14.8% for boys). Amongst unhealthy activities, girls particularly cited smoking (9.9% girls, 5.4% boys) and eating less healthily (20.8% girls and 16.6% boys). By contrast, consumption of alcohol and/or drugs as a coping strategy was cited by a greater percentage of boys (11.2% boys, 8.1% girls). The percentages of adolescents who had spoken to a mental health professional was 7.7% of girls and 2.6% of boys.

In the logistic regression analysis adjusted for gender, house size and type of educational centre an association was observed between the use of social activities to cope with the pandemic, particularly family activities (OR=0.59; CI95%=0.44-0.80) and reserving time to be with those you live with (OR=0.70; CI95%=0.50-0.98) with a lower probability of declaring worsening of mental health due to the pandemic. Playing board games, puzzles or crafting also showed a protective effect in relation to worsening of mental health (OR=0.56; CI95%=0.41-0.78). For adolescents who reported other strategies related to unhealthy habits, like consumption of alcohol or drugs (OR=2.10; CI95%=1.35-3.27), and/or smoking (OR=1.93; IC95%=1.21-3.08), a greater probability of perceiving a negative impact of the pandemic on mental health was observed. Finally, adolescents who had spoken to mental health professionals reported a higher proportion of worsening of mental health (OR=3.62; CI95%=2.05-6.39).

IMPACT OF THE COVID-19 PANDEMIC ON THE PSYCHOLOGICAL WELL-BEING OF ADOLESCENTS BY GENDER IDENTITY

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Resumen

Objetivo: Evaluar el impacto de la COVID-19 en el bienestar emocional de adolescentes en Cataluña, y comparar las estrategias de afrontamiento adoptadas durante la pandemia y su relación con el impacto autopercibido de la COVID-19 en la salud mental según identidad de género. **Métodos:** Estudio transversal en centros educativos de Cataluña incluyendo 1.171 alumnos/as >15 años (octubre-diciembre de 2021). Mediante modelos de regresión logística multivariantes se evaluó la asociación entre las estrategias de afrontamiento y el impacto autopercibido de la pandemia en la salud mental. **Resultados:** Una mayor proporción de chicas que de chicos percibía un empeoramiento en su salud mental por la COVID-19 (36,9% y 17,8%, respectivamente). Las principales emociones reportadas tanto en chicas como en chicos fueron preocupación y aburrimiento. Se observó una asociación entre estrategias de afrontamiento positivas y una menor probabilidad de declarar un empeoramiento en la salud mental a raíz de la pandemia entre las chicas, mientras que otras estrategias relacionadas con hábitos poco saludables se asociaron a una mayor probabilidad de declarar un empeoramiento de la salud mental en ambos chicas y chicos. **Conclusión:** Este estudio demuestra el impacto negativo de la pandemia de la COVID-19 en el bienestar psicológico de los/las adolescentes, especialmente en chicas. Es importante seguir monitorizando el impacto de la COVID-

19 a medio/largo plazo en la salud mental de los/las adolescentes y disponer de información que pueda mejorar el desarrollo de estrategias de afrontamiento saludables durante crisis de salud como la COVID-19 considerando una perspectiva de género.

Palabras clave: COVID-19; Bienestar psicológico; Adolescentes; Identidad de género; Escuelas; Estudio transversal

Abstract

Objective: To describe the impact of the COVID-19 pandemic on the psychological well-being of adolescents in Catalan schools by gender identity, and to compare coping strategies adopted to manage the health crisis and their relationship with the self-perceived impact of COVID-19 on mental health. **Methods:** Cross-sectional study in educational centres that includes 1,171 adolescents over 15 years old. Online questionnaire (on paper when necessary) implemented from October to November 2021. Multivariate logistic regression models were built to evaluate the association between coping strategies with self-perceived impact of the pandemic on mental health. **Results:** A greater proportion of girls perceived a worsening in mental health than boys due to COVID-19 (36.9% and 17.8%, respectively). The main emotions reported for both girls and boys were worry and boredom. The study found an association between positive coping strategies with less adverse mental health among girls, whereas unhealthy habits were associated with a higher probability of declaring worsening of mental health for both girls and boys. **Conclusion:** This study demonstrated the negative impact of the COVID-19 pandemic on psychological well-being in adolescents and a clearly worse impact on girls. It is important to keep monitoring the medium- and long-term secondary impacts of the pandemic on mental health outcomes of adolescents and to gather information that can improve services for the development of healthy coping strategies during health crises like COVID-19, which include gender perspective.

Keywords: COVID-19; Psychological well-being, Adolescents; Gender Identity; Schools; Cross-Sectional studies

Introduction

The SARS-CoV-2 emergency affected health systems globally, compelling governments to implement strategies, like social distancing or confinements, and generating stress,

anxiety, and depression which impacted the population well-being, and young people especially (Nearchou et al. 2020). In educational settings, measures such as suspending classes and accelerating the use of technology for learning, had an impact on the routines of students and their families (Krishnaratne et al. 2020). Additionally, social distancing reduced the interpersonal interactions and leisure activities of adolescents, who lost social relations with peers, amongst other changes (Orgilés et al. 2020). Previous systematic reviews have demonstrated that mental health problems in children and adolescents increased during the pandemic compared to pre-pandemic data, being gender, socio-economic status, previous state of mental and physical health, social support, and consistent routines among the most reported influencing factors (Wolf and Schmitz 2023; Saulle et al. 2022; Kauhanen et al. 2023; Amorós-Reche et al. 2022; Theberath et al. 2022).

Several studies have shown gender differences in the response of adolescents to the COVID-19 pandemic, with a worse effect on psychological well-being observed in girls (Kang et al. 2020; Halldorsdottir et al. 2021). Reasons cited for the gender differences include a reduction in emotional support from social networks due to social distancing (Magson et al. 2021) and a greater increase in unhealthy lifestyle habits compared to boys (Kang et al. 2020). Additionally, depression and anxiety increase during puberty, especially among girls (Knight et al. 2021), which may partially explain these gender disparities. The pandemic highlighted gender differences in mental health that are a reflection of the distinct social processes for youth with different gender identities, as well as disparities in mental health that emerge and intensify during this stage of life (Hoyt et al. 2023).

Effective coping strategies, defined as cognitive and behavioural efforts made to manage situations that are potentially threatening or stressful (Folkman and Lazarus 1980), have been reported in adolescents, such as physical activity, use of social networks and establishing routines (Golemis et al. 2022; Dvorsky et al. 2022). However, unhealthy coping strategies such as consumption of tobacco, alcohol and/or drugs, or unhealthy eating habits have been identified, although to a lesser extent (Romano et al. 2021; Lin et al. 2021). Evidence indicates that positive coping strategies, such as connecting with friends and family members and/or engaging in physical activities, are closely related to better mental health outcomes during the COVID-19 pandemic (Theberath et al. 2022), whereas unhealthy coping strategies relate more strongly to greater negative impacts on stress and mental health. Also gender is one of the factors that influences which coping

strategies are adopted to confront stress (Halldorsdottir et al. 2021; Molero Jurado et al. 2021) . A previous study in Spain on a sample of university students showed that men resorted to physical exercise during the pandemic, while women listened to more music and watched more television (Marco-Ahulló, Villarrasa-Sapiña, and Monfort-Torres 2021).

The COVID-19 Sentinel Schools Network of Catalonia [CSSNC], main objective was to monitor and evaluate the COVID-19 situation and its impact in educational settings in order to gather evidence for the health policies, prevention and control of SARS-CoV-2 in schools. Since its implementation in 2020, mental health was identified as a priority challenge, leading us to include in the project new research questions to better explore this issue in schools and develop more effective strategies (Bordas et al. 2022).

This study aims to describe the impact of the COVID-19 pandemic on psychological well-being, defined as "a state of mind in which an individual is able to develop their potential, work productively, and creatively, and is able to cope with the normal stresses of life" (Dr. M. Dhanabhakya and Sarath M 2023), in students over 15 years in CSSNC stratified by gender identity. Furthermore, the study aims to compare coping strategies adopted to manage the health crisis by gender and to investigate associations between strategies adopted and a worsening of mental health due to the COVID-19 pandemic. It is essential to explore how girls and boys were coping during the pandemic and what coping strategies positively or negatively influenced changes in mental health to be able to understand the impacts of the pandemic and to better inform appropriate school-based interventions, creating a safe and supportive environment that responds to their specific needs.

Methodology

Study design and participants selection

This is a cross-sectional study in 16 educational centres in Catalonia part of the CSSNC Project during 2021-2022 (Bordas et al. 2022). Although it was an opportunistic sample, epidemiological, sociodemographic characteristics, and type of school (public, private, or chartered) were considered to assure heterogeneity. For the objectives of this study, students aged 15-19 years-old were included. The study was approved by the ethics committee of the *IDIAP Jordi Gol i Gurina Foundation* on 17 December 2020 (20/192-PCV). Informed consent was obtained from all the participants.

Data collection

Data collection took place from October-November 2021 through a questionnaire developed on the REDCap platform, or in paper when necessary. Each school was responsible to send a link containing the informed consent and the questionnaire available in Catalan, Spanish and English to teaching and non-teaching staff and students. Students over 15 years old signed the informed consent and completed the questionnaire by themselves. Response rate was 53% and 23% for staff and students, respectively.

Variables

The questionnaire including sociodemographic and health status variables was based on the WHO/Europe recommendation (WHO 2020). The questions on impact of COVID-19 on psychological well-being of students and the coping strategies adopted were adapted from sections from the CASPE questionnaire. The full list of variables is presented in table 1.

Table 1. List of variables included in the questionnaire.

<i>Sociodemographic variables:</i>	Type of educational centre; according to complexity (low, medium low, medium high, high or very high) age, country of birth, level of studies of parents or tutors, change in household income since the start of the pandemic (Increased, Decreased, No change, Unknown), living with people of 65 or over and/or with children and/or with healthcare professionals, house size. Gender identity options were female/male/non-binary/other. Female or male are also referred to as girl or boy below.
<i>Health status:</i>	Self-perceived physical health (excellent, very good, good, fair, poor), self-perceived mental health (excellent, very good, good, fair, poor), having a chronic illness, diagnosis for anxiety, and previous infection with COVID-19.
<i>Self-perceived impact of the pandemic on mental health:</i>	It has improved, it has worsened, and it has stayed the same.

<i>Level of stress caused by uncertainty about the future generated by COVID-19</i>	Using a Likert 7-point scale between 1 (less stressful) and 7 (more stressful).
<i>Emotions felt in the last 7 days caused by the pandemic</i>	Using a Likert 5-point scale between 1 (very slightly or not at all) and 5 (extremely). The emotions reported on were anxiety or stress, fear, sadness, worry, irritability, loneliness, boredom, disappointment and frustration. From the answers for each emotion an indicator was created with the sum of the 9 emotions lived (range 9-45) where higher values on the scale were related to worse psychological well-being.
<i>Level of concern about the impact of the pandemic on different aspects of life in relation to the last 7 days</i>	Using a 5-point Likert scale between 1 (very little or not at all) and 5 (a great deal).
<i>Strategies used to cope with the pandemic</i>	Participants had to select from a list coping strategies that were later classified as 1) Strategies related to social activities; 2) Strategies related to solitary digital activities; 3) Self-care strategies; 4) Strategies related with unhealthy habits; 5) Others, following previous studies using CASPE questionnaire.

Variable sources (i) Survey Tool and Guidance for Behavioural Insights on COVID-19: Monitoring Knowledge, Risk Perceptions, Preventive Behaviours and Trust to Inform Pandemic Outbreak Response: Copenhagen. WHO Regional Office for Europe; 2020. <https://Apps.Who.Int/Iris/Bitstr>, (ii) Ladouceur, CD. 2020. “Adolescent Symptom and Psychological Experience Questionnaire [CASPE].” Pittsburgh, PA.

Statistical analysis

Differences between proportions according to gender were compared using the Chi-Square, or the exact Fisher’s exact test when more than 20% of cells have expected frequencies < 5, and differences between means using the Student’s T-Test. Only people identifying as men or women were included in the analysis because the small number of participants identified themselves as non-binary or other (12 people identified themselves as non-binary and 48 did not want to answer the question).

Logistic regression models were built to evaluate the association between coping strategies with self-perceived impact of the pandemic on mental health, adjusting by

gender, house size and type of educational centre according to complexity. The dependent variable “self-perceived impact of the pandemic on mental health” was dichotomized as “it has improved or stayed the same” versus “it has worsened”. Adjusted OR (Ora) were calculated with a Confidence Interval of 95% (IC95%). The level of statistical significance was established as 0.05. All analyses were carried out using the R program, version 4.1.2.

Results

Of a total of 1,171 participants, 626 (55.7%) identified as women, 478 (42.6%) identified as men, 12 (1.1%) as non-binary and 7 (0,6%) as other gender. Regarding complexity, 166 (14.2%) students were from low complexity schools, 140 (12.0%) medium low complexity, 700 (59.8%) medium high and the rest (14.1%) from high complexity schools.

The mean age of participating boys and girls was 16.9 and 16.8 years old respectively, most were born in Spain (89.9% girls and 93.0% boys) and 9.3% of girls and 8.5% of boys, respectively, reported a lower level of family income since the start of the pandemic. A higher proportion of boys compared to girls reported a university level of education for their mothers (36.4% boys and 29.7% girls) (table 2).

Boys presented a better self-perceived general health compared to girls (95.3% good, very good or excellent for boys and 92.3% for girls) and better self-perceived mental health (87.3% good, very good or excellent for boys and 63.8% for girls). Additionally, the percentage diagnosed with anxiety before or after the pandemic started was higher in girls (20.6% girls, 7.3% boys) (Table 2).

Table 2. Socio-demographic and health status characteristics of the sample according to gender identity

Variables*	Girls (N=626)		Boys (N=478)		P
	N	%	N	%	
Socio-demographics					
Mean age [SD]	16.9	SD: 1.0	16.8	SD: 1.0	0,102
Place of birth: Spain	551	89.9	436	93.0	0.076
Level of education (fathers)					0.108
Primary or less	137	21.9	79	16.5	
Secondary	235	37.5	179	37.4	
University	147	23.5	132	27.6	

Unknown or not applicable	107	17.1	88	18.4	
Level of education (mothers)					0.002
Primary or less	106	16.9	47	9.8	
Secondary	249	39.8	181	37.9	
University	186	29.7	174	36.4	
Unknown or not applicable	85	13.6	76	15.9	
Level of education (guardians)					0.141
Primary or less	25	4.0	17	3.6	
Secondary	69	11.0	46	9.6	
University	46	7.3	54	11.3	
Unknown or not applicable	486	77.6	361	75.5	
Size of home (m ²): More than 70 m ²	544	88.8	390	82.4	0.006
Living with children	296	48.4	236	51.0	0.412
Living with people >65	51	8.4	32	6.9	0.379
Living with healthcare professionals	96	15.7	59	12.7	0.167
Lower level of income (since COVID-19)	57	9.3	40	8.5	0.631
Health status					
Self-perceived health: excellent/very good/good	550	92.3	444	95.3	0.045
Self-perceived mental health: excellent/very good/good	380	63.8	459	87.3	<0.001
Any chronic disease	60	10.1	40	8.6	0.411
Diagnosis for anxiety					<0.001
Never	473	79.4	432	92.7	
Yes, since the pandemic started	52	8.7	11	2.4	
Yes, before the pandemic	71	11.9	23	4.9	
Previous infection with COVID-19	128	20.4	82	17.2	0.151

*Missing values not included in calculations (for all variables missing values were <10%)

A greater proportion of girls perceived a worsening in mental health due to the COVID-19 compared to boys (36.9% and 17.8%, respectively), while 5.7% of girls and 15.0% of boys perceived their mental health as improved in this same period ($p < 0.001$). Additionally, the level of stress caused by uncertainty about the future generated for COVID-19 was also greater in girls than in boys ($M = 4.1$ [SD:1.7] and $M = 3.1$ [SD:1.8], respectively) (Table 3).

Table 3. Level of stress caused by uncertainty about the future generated by COVID-19 and emotions felt by gender identity.

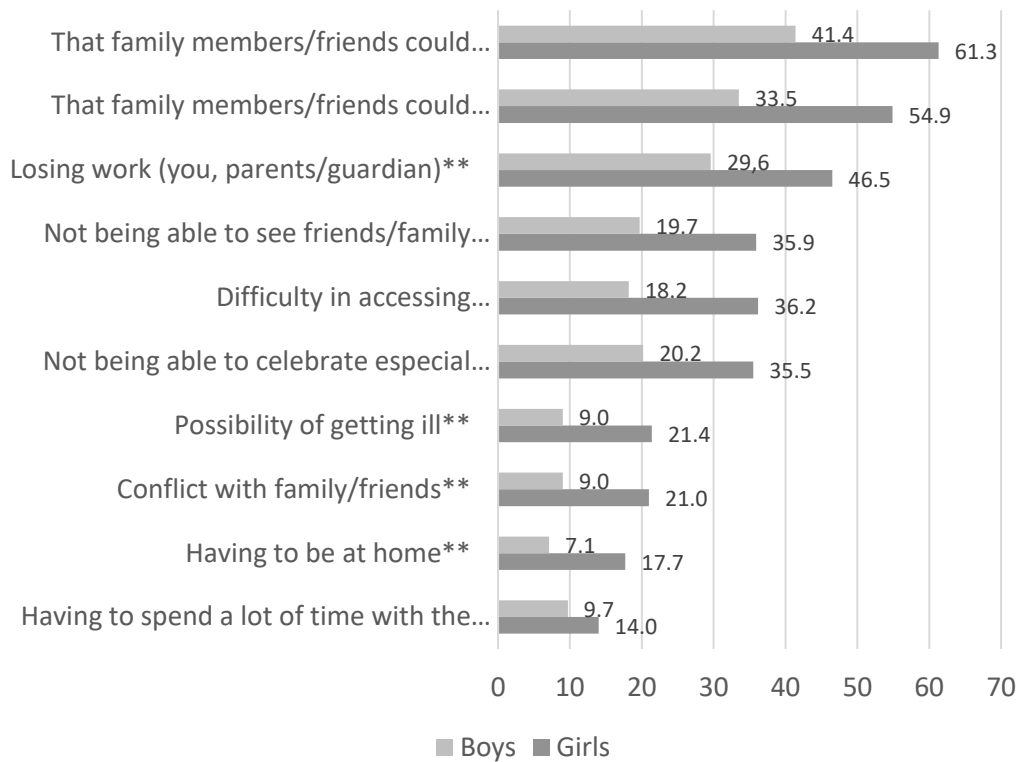
Variables	Girls (N=626)		Boys (N=478)		P
	Mean	SD	Mean	SD	
Self-perceived stress associated with the pandemic ^{a, b}	4.1	[1.7]	3.1	[1.8]	<0.001
Emotions felt because of the pandemic ^{a, c}					

Anxiety or stress	2.4	[1.3]	1.7	[1.0]	<0.001
Fear	1.9	[1.0]	1.4	[0.7]	<0.001
Sadness	2.4	[1.1]	1.7	[0.9]	<0.001
Worry	2.7	[1.1]	2.2	[1.1]	0.255
Irritability	2.3	[1.2]	1.8	[1.0]	<0.001
Loneliness	2.1	[1.2]	1.6	[1.0]	<0.001
Boredom	2.7	[1.3]	2.4	[1.2]	0.044
Disappointment	2.3	[1.3]	1.9	[1.1]	<0.001
Frustration	2.5	[1.3]	1.8	[1.0]	<0.001
Total score	21.2	[8.0]	16.4	[6.4]	<0.001

^a Last 7 days; ^b 7-option Likert scale from 1 (less stressful) and 7 (more stressful). ^c 5-option Likert scale from 1 (very slightly or not at all) and 5 (extremely). SD: Standard Deviation

For all the emotions that can generate emotional discomfort, girls had statistically significant higher mean scores than boys, except for worry (Table 3). The main emotions reported for both girls and boys, respectively, were worry (M=2.7 [SD:1.1] and M=2.2 [SD:1.1],) and boredom (M=2.7 [SD:1.3] and M=2.4 [SD:1.2],), followed by frustration in girls (M=2.5 [SD:1.3]) and disappointment in boys (M=1.9 [SD:1.1]).

Most of the participants reported a high negative impact of the pandemic caused by the fact that friends or family could die (61.3% girls and 41.4% boys) and/or get sick (54.9% girls and 33.5% boys), together with the fear of losing jobs (themselves or family members) (46.5% girls and 29.6% boys) (Figure 1).



*p=0.05; **p<0.001

Figure 1. Level of concern (a lot/a great deal) about the impact of the pandemic on distinct aspects of life according to gender identity

One of the most frequent coping strategies used by adolescents to deal with the pandemic (table 4) was contact with friends online and/or social media (76.5% and 68.6% in boys and girls respectively), and other solitary digital activities like watching TV and/or films (80.8% and 69.7% in girls and boys respectively). On the other hand, playing videogames was an activity mainly reported by boys (78.7% and 28.1%, respectively). In addition, other social activities related to family such as reserving time to spend with people they lived with were more frequently reported by girls in comparison with boys (26.4% and 20.6%, respectively). More than half the adolescents also referred to self-care strategies like taking exercise (59.7% and 63.2% in girls and boys, respectively), and/or other individual non-digital activities such as reading and/or writing, higher among girls (41.2% girls and 14.8% boys). Amongst unhealthy activities, girls reported smoking as a coping strategy more frequently than boys (9.9% girls, 5.4% boys), while eating less healthily (20.8% girls and 16.6% boys), and consumption of alcohol and/or drugs (11.2% boys, 8.1% girls) were reported similarly by gender. The percentage of girls who had

spoken to a mental health professional was higher than boys (7.7% of girls and 2.6% of boys).

Table 4. Strategies used to cope with the pandemic by gender identity.

	Girls (N=626)		Boys (N=478)		P
	N	%	N	%	
Social activities					
Be in contact with friends online/social media	455	76.5	319	68.6	0.004
Participate in family activities	220	37.0	157	33.8	0.278
Reserve time to spend with people I live with	157	26.4	96	20.6	0.030
Solitary digital activities					
Watch TV/films	481	80.8	324	69.7	<0.001
Play videogames	167	28.1	366	78.7	<0.001
Other non-digital solitary activities					
Practice meditation/mindfulness/praying	69	11.6	19	4.1	<0.001
Writing/reading	245	41.2	69	14.8	<0.001
Play an instrument/listen to music	236	39.7	130	28.0	<0.001
Play board games, puzzles or crafting	195	32.8	102	21.9	<0.001
Self-care strategies					
Try to improve nocturnal rest	158	26.6	113	24.3	0.404
Do exercise	355	59.7	294	63.2	0.238
Eat more healthily	167	28.1	111	23.9	0.123
Unhealthy activities					
Eat less healthily	124	20.8	77	16.6	0.078
Drink alcohol and/or take drugs	48	8.1	52	11.2	0.085
Smoking	59	9.9	25	5.4	0.007
Other strategies					
Take vitamins/herbal remedies for immune system	46	7.7	16	3.4	0.003
Speak with mental health professionals	46	7.7	12	2.6	<0.001
Spend time in private outdoor areas	123	20.7	62	13.3	0.002
Follow a daily routine of activities	185	31.1	135	29.0	0.468

In the adjusted logistic regression analysis, we founded an association between the participation in family activities, such as playing games and/or sports, with a lower probability of declaring worsening of mental health due to the pandemic among girls (OR=0.55; CI95%=0.38-0.79) (Table 5).

Table 5. Association between strategies to cope with the pandemic and worsening of mental health adjusted by gender identity

	Girls (N=626)			Boys (N=478)		
	aOR	IC95%	p	aOR	IC95%	p
Social activities						
Be in contact with friends online/social media	1.18	0.79-1.76	0.430	1.03	0.61-1.74	0.923
Participate in family activities (games, sports etc.)	0.55	0.38-0.79	0.001	0.69	0.41-1.17	0.171
Reserve time to spend with people I live with	0.70	0.47-1.03	0.07	0.78	0.41-1.46	0.436
Solitary digital activities						
Watch TV/films	0.75	0.55-1.31	0.467	0.85	0.51-1.42	0.538
Play videogames	0.66	0.45-0.97	0.036	1.32	0.70-2.49	0.387
Other non-digital solitary activities						
Practice meditation/mindfulness/praying	1.33	0.80-2.22	0.271	1.26	0.40-3.93	0.693
Writing/reading	1.23	0.87-1.73	0.242	0.75	0.36-1.55	0.441
Play an instrument/listen to music	1.31	0.93-1.86	0.122	1.25	0.74-2.10	0.402
Play board games, puzzles or crafting	0.62	0.43-0.89	0.011	0.44	0.22-0.88	0.021
Self-care strategies						
Try to improve nocturnal rest	1.08	0.74-1.58	0.676	0.96	0.54-1.70	0.895
Do exercise	1.33	0.94-1.88	0.107	0.74	0.45-1.20	0.223
Eat more healthily	1.01	0.69-1.47	0.964	0.90	0.51-1.61	0.731
Unhealthy activities						
Eat less healthily	1.26	0.84-1.91	0.268	1.20	0.65-2.24	0.557
Drink alcohol and/or take drugs	2.61	1.41-4.81	0.002	1.56	0.79-3.11	0.203
Smoke	1.70	0.98-2.94	0.058	2.45	1.03-5.84	0.043
Other strategies						
Take vitamins or herbal remedies for immune system	1.02	0.54-1.90	0.958	0.70	1.55-3.20	0.649
Speak with mental health professionals	3.43	1.82-6.46	<0.001	4.56	1.31-15.9	0.017
Spend time in private outdoor areas	0.90	0.59-1.37	0.611	0.74	0.33-1.63	0.451
Follow a daily routine of activities	0.86	0.59-1.24	0.419	1.03	0.61-1.75	0.911

*aOR: Odds ratio adjusted by house size and type of educational centre according to complexity

Playing board games, puzzles or crafting also showed a protective effect in relation to worsening of mental health among both girls and boys, respectively (OR=0.62; CI95%=0.43-0.89 for girls and OR=0.44; CI95%=0.22-0.88 for boys). Playing

videogames also showed a protective effect in relation to worsening of mental health among girls (OR=0.66; CI95%=0.45-0.97).

Among girls, other strategies related to unhealthy habits, like consumption of alcohol or drugs, were associated with a higher probability of declaring worsening of mental health due to the pandemic (OR=2.61; CI95%=1.41-4.81). An association between smoking and a higher probability of declaring worsening of mental health due to the pandemic was seen among boys (OR=2.45; CI95%=1.03-5.84).

Finally, adolescents who had spoken to mental health professionals reported a higher proportion of worsening of mental health (OR=3.43; CI95%=1.82-6.46 for girls and OR=4.56; CI95%=1.31-15.9 for boys) (Table 5).

Discussion

This study demonstrated the negative impact of the COVID-19 pandemic on psychological well-being in adolescents and a clearly worse impact on girls. The use of social and digital media to keep in contact with friends and reduce social isolation was the most commonly reported coping strategy for both girls and boys, whereas gender differences were seen in the use of other strategies used such as the higher proportion of girls using social activities related to family and/or friends in comparison to boys. This study also shows an association between coping strategies and self-perceived mental health status in adolescents in Catalonia. In this sense, the use of unhealthy habits during the early pandemic period (e.g., substance use) was associated with a higher probability of declaring worsening mental health among both girls and boys, whereas the use of other positive coping strategies (e.g., spending time with family) was associated with less adverse mental health among girls.

The higher percentage of girls than boys that perceived a worsening of mental health due to the pandemic and the higher level of stress caused by general uncertainty it produced is consistent with others studies (Orgilés et al. 2020; Wolf and Schmitz 2023; Saulle et al. 2022; Kauhanen et al. 2023; Theberath et al. 2022; Amorós-Reche et al. 2022). Emerging evidence indicates that girls perceive the impact of COVID-19 on their psychological well-being differently from boys (Pigaiani et al. 2020). However, a higher prevalence of diagnoses of anxiety since the start of the pandemic observed in the study (8.7% girls, 2.4% boys) suggests that objective data exists to confirm the worsening of mental well-being in girls. All adolescents experienced more intense emotions than usual

linked to the pandemic such as: worry, boredom, frustration, and disappointment, with girls presenting higher mean scores on most of the emotions that negatively affected psychological well-being. Other studies with children and adolescents in Spain during the first months of the pandemic revealed feelings like fear, sadness and boredom, typical of the break with routine and loss of predictability the pandemic supposed (Amorós-Reche et al. 2022). Although no difference was observed in type of concerns most reported according to gender, there were differences in intensity with girls showing the highest prevalence, as reported previously (Hassan et al. 2021). The fact that family or friends could die if infected by SARS-CoV-2 was the commonest concern reported for both genders; a risk factor for poorer psychological well-being in young people observed in several studies (Balluerka-Lasa, Gómez-Benito, and Hidalgo-Montesinos 2020). The second major stressor was fear of losing work, both for themselves and/or family members, consistent with a previous study in Catalonia where a decline in family income was associated with poorer overall well-being for girls and boys boys (Tzur Bitan et al. 2020)

Amongst the most common strategies found in our study to cope with the pandemic, for both girls and boys, were maintaining contact with friends online or through social media, together with other solitary digital activities. Although that coping strategies alleviate the effects of social distancing, social network use has also been associated with negative psychological consequences in this context (Folch et al. 2022).

Girls reported in a higher proportion than boys the use of social activities related to family and/or friends as a coping strategy, as observed previously (Clark, Algoe, and Green 2018). In addition, among girls, spending time with family members was associated with less likelihood of declaring worsening mental health due to the pandemic. Other studies also show that better communication and emotional support from family members during the pandemic was a protection against developing symptoms of anxiety or depression in children and adolescents (Riazi et al. 2023).

As in other studies (Tang et al. 2021) a large percentage of adolescents referred to self-care strategies like exercise to deal with the pandemic, which has shown mental health benefits for the young. However, other less healthy habits like smoking, and consumption of alcohol and/or drugs, were also used as coping strategies (Pascoe et al. 2020). Compared to boys, more girls in our sample reported engaging in tobacco use to cope with the pandemic. This finding is consistent with evidence that girls may be more likely to use substances as a coping strategy and responds to their learning and development, as

well as their mental health and psychosocial well-being needs (Rogés et al. 2021), but some studies have shown that users had increased the intensity and frequency of their intake (Romano et al. 2021). Worry and fear due to COVID-19, together with consumption to relieve feelings of emotional discomfort caused by anxiety, stress or depressive feelings, have been identified as factors associated with coping strategies involving substance use (Fox and Sinha 2009).

Finally, seeking professional help as a coping strategy was reported by a few number of adolescents, and more in girls, in line with previous studies showing young people will more often disclose their feelings to parents and friends than to professionals, this is in part due to mental health stigma and embarrassment, a lack of mental health knowledge and negative perceptions of help-seeking (Grove, Marinucci, and Montagni 2023)

Some limitations of this study include a lack of pre-pandemic data to confirm a real decrease in mental health in adolescents using internationally validated scales. However, the questionnaire used was created specifically to measure perception of impact of the pandemic on psychological well-being in adolescents and was never intended to diagnose the real state of mental health of participants. On the other hand, as it is a transversal study, we cannot establish causality between worsening mental health and coping strategies adopted. Additionally, we cannot rule out a significant degree of memory bias, as in any retrospective survey. Finally, considering the non-probabilistic sampling method, the results cannot be generalized to the school population of Catalonia. However, one of the most important strengths of this study was the formation of a network of schools that worked together to develop, adapt and implement health protocols, studies and scientific dissemination in the face of the pandemic, providing safe attendance of face-to-face activities for students and education professionals. Still, in relation to the methodology, the study design, carried out concomitantly with the participatory research model, revealed a strengthening of science teaching and the strengthened student involvement, seeking to mitigate as much as possible the impact of the pandemic on their mental health.

In conclusion, this study presents evidence on the negative impact of the COVID-19 pandemic on psychological well-being in adolescents in schools in Catalonia, especially in girls. Although the generalized use of social media technology as a coping strategy stands out, other activities and strategies have been employed, and differently by boys and girls. Some of these strategies have been related to better psychological well-being,

but we must not forget that unhealthy strategies, such as consumption of alcohol and/or drugs and smoking, have also increased to deal with difficult situations. Due to the pandemic adolescents experienced much stronger negative emotions than usual such as worry, irritability or frustration; with girls presenting a higher proportion of them. More focus must be put on feelings generating emotional discomfort, especially if they are very intense and prolonged, because the absence of adequate tools to manage them can put those who experience them at risk. It is important to keep monitoring the medium- and long-term secondary impacts of the pandemic on mental health outcomes and consequent coping behaviours, especially considering gender perspective.

Finally, access for adolescents to emotional support services must be improved, both within schools and in specialized mental health centres, taking into account the need to support young people as they develop the necessary positive coping strategies required during health crises such as that of COVID-19.

References

- Adane, Metadel, Ayechev Ademas, and Helmut Kloos. 2022. "Knowledge, Attitudes, and Perceptions of COVID-19 Vaccine and Refusal to Receive COVID-19 Vaccine among Healthcare Workers in Northeastern Ethiopia." *BMC Public Health* 22 (1): 128. <https://doi.org/10.1186/s12889-021-12362-8>.
- Ainslie, Kylie E C, Jantien A Backer, Pieter T De Boer, Albert Jan Van Hoek, Don Klinkenberg, Hester Korthals Altes, Ka Yin Leung, Hester De Melker, Fuminari Miura, and Jacco Wallinga. 2022. "A Scenario Modelling Analysis to Anticipate the Impact of COVID-19 Vaccination in Adolescents and Children on Disease Outcomes in the Netherlands, Summer 2021." *Eurosurveillance* 27 (44). <https://doi.org/10.2807/1560-7917.ES.2022.27.44.2101090>.
- Amorós-Reche, Víctor, Àngela Belzunegui-Pastor, Gaspar Hurtado, and Jose P. Espada. 2022. "Emotional Problems in Spanish Children and Adolescents during the COVID-19 Pandemic: A Systematic Review." *Clínica y Salud* 33 (1): 19–28. <https://doi.org/10.5093/clysa2022a2>.
- Balluerka-Lasa, N, J Gómez-Benito, and MD Hidalgo-Montesinos. 2020. "Las Consecuencias Psicológicas de La Covid-19 y El Confinamiento." Servicio de Publicaciones de la Universidad del País Vasco.
- Bastos, Leonardo S, Theodoros Economou, Marcelo F C Gomes, Daniel A M Villela, Flavio C Coelho, Oswaldo G Cruz, Oliver Stoner, Trevor Bailey, and Claudia T Codeço. 2019. "A Modelling Approach for Correcting Reporting Delays in Disease Surveillance Data." *Statistics in Medicine* 38 (22): 4363–77. <https://doi.org/10.1002/sim.8303>.
- Bellei, Nancy, and Thaís Boim Melchior. 2011. "H1N1: Pandemia e Perspectiva Atual." *Jornal Brasileiro de Patologia e Medicina Laboratorial* 47 (6): 611–17. <https://doi.org/10.1590/S1676-24442011000600007>.

- Bi, Qifang, Yongsheng Wu, Shujiang Mei, Chenfei Ye, Xuan Zou, Zhen Zhang, Xiaojian Liu, et al. 2020. "Epidemiology and Transmission of COVID-19 in 391 Cases and 1286 of Their Close Contacts in Shenzhen, China: A Retrospective Cohort Study." *The Lancet Infectious Diseases* 20 (8): 911–19. [https://doi.org/10.1016/S1473-3099\(20\)30287-5](https://doi.org/10.1016/S1473-3099(20)30287-5).
- Bordas, Anna, Antoni Soriano-Arandes, Maria Subirana, Rosina Malagrida, Juliana Maria Reyes-Urueña, Cinta Folch, Pere Soler-Palacin, et al. 2022. "Study Protocol for Monitoring SARS-CoV-2 Infection and Its Determinants in Catalonia (Spain): An Observational and Participatory Research Approach in a Sentinel Network of Schools." *BMJ Open* 12 (1): e055649. <https://doi.org/10.1136/bmjopen-2021-055649>.
- Bubar, Kate M, Kyle Reinholt, Stephen M Kissler, Marc Lipsitch, Sarah Cobey, Yonatan H Grad, and Daniel B Larremore. 2021. "Model-Informed COVID-19 Vaccine Prioritization Strategies by Age and Serostatus."
- Byrne, Alexandra, Lindsay A. Thompson, Stephanie L. Filipp, and Kathleen Ryan. 2022. "COVID-19 Vaccine Perceptions and Hesitancy amongst Parents of School-Aged Children during the Pediatric Vaccine Rollout." *Vaccine* 40 (46): 6680–87. <https://doi.org/10.1016/j.vaccine.2022.09.090>.
- Ceannt, Ruth, Frederique Vallieres, Heather Burns, Jamie Murphy, and Philip Hyland. 2022. "Covid-19 Vaccine Hesitancy and Resistance amongst Parents of Children under 18 Years of Age in Ireland." *Vaccine* 40 (43): 6196–6200. <https://doi.org/10.1016/j.vaccine.2022.08.073>.
- Centre for Disease Prevention, European. 2021. "COVID-19 Surveillance Guidance."
- Choe, Young June, Young-Joon Park, Eun-Young Kim, Myoungyoun Jo, Eun Young Cho, Hyunju Lee, Yun-Kyung Kim, Yae-Jean Kim, and Eun Hwa Choi. 2021. "SARS-CoV-2 Transmission in Schools in Korea: Nationwide Cohort Study." *Arch Dis Child* 0: 1–5. <https://doi.org/10.1136/archdischild-2021-322355>.
- Chowell, Gerardo, Fatima Abdirizak, Sunmi Lee, Jonggul Lee, Eunok Jung, Hiroshi Nishiura, and Cécile Viboud. 2015. "Transmission Characteristics of MERS and SARS in the Healthcare Setting: A Comparative Study." *BMC Medicine* 13 (1): 210. <https://doi.org/10.1186/s12916-015-0450-0>.
- Clark, Jenna L., Sara B. Algoe, and Melanie C. Green. 2018. "Social Network Sites and Well-Being: The Role of Social Connection." *Current Directions in Psychological Science* 27 (1): 32–37. <https://doi.org/10.1177/0963721417730833>.
- Cowling, B J, M Park, V J Fang, P Wu, G M Leung, and J T Wu. 2015. "Preliminary Epidemiological Assessment of MERS-CoV Outbreak in South Korea, May to June 2015." *Eurosurveillance* 20 (25). <https://doi.org/10.2807/1560-7917.ES2015.20.25.21163>.
- Crawshaw, Alison F., Yasmin Farah, Anna Deal, Kieran Rustage, Sally E. Hayward, Jessica Carter, Felicity Knights, et al. 2022. "Defining the Determinants of Vaccine Uptake and Undervaccination in Migrant Populations in Europe to Improve Routine and COVID-19 Vaccine Uptake: A Systematic Review." *The Lancet. Infectious Diseases* 22 (9): e254–66. [https://doi.org/10.1016/S1473-3099\(22\)00066-4](https://doi.org/10.1016/S1473-3099(22)00066-4).
- Cupertino, Vita, Elena Bozzola, Giampaolo De Luca, Emanuela Del Giudice, Giuseppe De Martino, Piero Cannataro, Alberto Eugenio Tozzi, and Giovanni Corsello. 2022. "The Awareness and Acceptance of Anti-COVID 19 Vaccination in Adolescence." *Italian Journal of Pediatrics* 48 (1): 194. <https://doi.org/10.1186/s13052-022-01390-8>.

- Dao, Thi Loi, Hue Vu Thi, Philippe Gautret, Jaffar A. Al-Tawfiq, Thanh Lam Nguyen, Dinh Toi Chu, and Van Thuan Hoang. 2023. "Willingness and Attitudes of Parents towards COVID-19 Vaccines for Children in Vietnam." *Journal of Communication in Healthcare* 16 (1): 75–82. <https://doi.org/10.1080/17538068.2022.2150207>.
- Dembek, Z. F., T. Chekol, and A. Wu. 2018. "Best Practice Assessment of Disease Modelling for Infectious Disease Outbreaks." *Epidemiology and Infection* 146 (10): 1207–15. <https://doi.org/10.1017/S095026881800119X>.
- Diaz-Quijano, Fredi A., José M.N. da Silva, Fabiana Ganem, Silvano Oliveira, Andrea L. Vesga-Varela, and Julio Croda. 2020. "A Model to Predict SARS-CoV-2 Infection Based on the First Three-Month Surveillance Data in Brazil." *Tropical Medicine and International Health* 25 (11): 1385–94. <https://doi.org/10.1111/tmi.13476>.
- Dong, Ensheng, Hongru Du, and Lauren Gardner. 2020. "An Interactive Web-Based Dashboard to Track COVID-19 in Real Time." *The Lancet Infectious Diseases* 20 (5): 533–34. [https://doi.org/10.1016/S1473-3099\(20\)30120-1](https://doi.org/10.1016/S1473-3099(20)30120-1).
- Dr. M. Dhanabhakym and Sarath M. 2023. "Psychological Wellbeing: Asystematic Literature Review." *International Journal of Advanced Research in Science, Communication and Technology*, February, 603–7. <https://doi.org/10.48175/IJARSCT-8345>.
- Drosten, Christian, Stephan Günther, Wolfgang Preiser, Sylvie Van Der Werf, Hans-Reinhard Brodt, Stephan Becker, Holger Rabenau, et al. 2003. "Identification of a Novel Coronavirus in Patients with Severe Acute Respiratory Syndrome." *New England Journal of Medicine* 348 (20): 1967–76. <https://doi.org/10.1056/NEJMoa030747>.
- Du, Yuxuan, Long Chen, and Yuan Shi. 2022. "Safety, Immunogenicity, and Efficacy of COVID-19 Vaccines in Adolescents, Children, and Infants: A Systematic Review and Meta-Analysis." *Frontiers in Public Health* 10: 829176. <https://doi.org/10.3389/fpubh.2022.829176>.
- Dubé, Eve, Dominique Gagnon, and Catherine Pelletier. 2022. "COVID-19 Vaccination in 5-11 Years Old Children: Drivers of Vaccine Hesitancy among Parents in Quebec." *Human Vaccines & Immunotherapeutics* 18 (1): 2028516. <https://doi.org/10.1080/21645515.2022.2028516>.
- Dvorsky, Melissa R., Rosanna Breaux, Caroline N. Cusick, Joseph W. Fredrick, Cathrin Green, Amanda Steinberg, Joshua M. Langberg, Emma Sciberras, and Stephen P. Becker. 2022. "Coping with COVID-19: Longitudinal Impact of the Pandemic on Adjustment and Links with Coping for Adolescents with and without ADHD." *Research on Child and Adolescent Psychopathology* 50 (5): 605–19. <https://doi.org/10.1007/s10802-021-00857-2>.
- ECDC. 2021. "Interim Public Health Considerations for COVID-19 Vaccination of Adolescents in the EU/EEA."
- Enria, Delia, Zijian Feng, Atle Fretheim, Chikwe Ihekweazu, Trygve Ottersen, Anne Schuchat, Kumnuan Ungchusak, et al. 2021. "Strengthening the Evidence Base for Decisions on Public Health and Social Measures." *Bulletin of the World Health Organization* 99 (09): 610-610A. <https://doi.org/10.2471/BLT.21.287054>.
- Ertem, Zeynep, Elissa M Schechter-Perkins, Emily Oster, Polly Berg, Isabella Epshtein, Nathorn Chaiyakunapruk, Fernando A Wilson, et al. 2021. "The Impact of School Opening Model on SARS-CoV-2 Community Incidence and Mortality." *Nature Medicine* 27: 2120–26. <https://doi.org/10.1038/s41591-021-01563-8>.

- Escosa-García, Luis, David Aguilera-Alonso, Cristina Calvo, María José Mellado, and Fernando Baquero-Artigao. 2020. "Ten Key Points about COVID-19 in Children: The Shadows on the Wall." *Pediatric Pulmonology* 55 (10): 2576–86. <https://doi.org/10.1002/ppul.25025>.
- España, Ministerio de Sanidad, and Grupo de trabajo técnico de vacunación COVID-19. 2021. "Estrategia de Vacunación Frente a COVID19 En España - Actualización 2." <https://www.sanidad.gob.es/profesionales/saludPublica/ccayes/alertasActual/nCov/vacunaCovid19.htm>.
- España, MP. 2020. "Real Decreto 463/2020, de 14 de Marzo, Por El Que Se Declara El Estado de Alarma Para La Gestión de La Situación de Crisis Sanitaria Ocasionada Por El COVID-19." Boletín Oficial del Estado 67. España: MINISTERIO DE LA PRESIDENCIA, RELACIONES CON LAS CORTES Y MEMORIA DEMOCRÁTICA. <https://www.boe.es/boe/dias/2020/03/14/pdfs/BOE-A-2020-3692.pdf>.
- Esposito, Susanna, Nicola Cotugno, and Nicola Principi. 2021. "Comprehensive and Safe School Strategy during COVID-19 Pandemic." *Italian Journal of Pediatrics* 47 (1): 6. <https://doi.org/10.1186/s13052-021-00960-6>.
- Folch, Cinta, Helena González-Casals, Joan Colom, Marina Bosque-Prous, Tivy Barón-Garcia, Anaís Álvarez-Vargas, Jordi Casabona, and Albert Espelt. 2022. "Mental Well-Being during the COVID-19 Confinement among Adolescents in Catalonia: The Role of Demographic and Other COVID-Related Variables." *Children* 9 (6): 783. <https://doi.org/10.3390/children9060783>.
- Folkman, Susan, and Richard S. Lazarus. 1980. "An Analysis of Coping in a Middle-Aged Community Sample." *Journal of Health and Social Behavior* 21 (3): 219. <https://doi.org/10.2307/2136617>.
- Fox, Helen C., and Rajita Sinha. 2009. "Sex Differences in Drug-Related Stress-System Changes: Implications for Treatment in Substance-Abusing Women." *Harvard Review of Psychiatry* 17 (2): 103–19. <https://doi.org/10.1080/10673220902899680>.
- Foy, Brody H., Brian Wahl, Kayur Mehta, Anita Shet, Gautam I. Menon, and Carl Britto. 2021. "Comparing COVID-19 Vaccine Allocation Strategies in India: A Mathematical Modelling Study." *International Journal of Infectious Diseases* 103 (February): 431–38. <https://doi.org/10.1016/j.ijid.2020.12.075>.
- Gallo, Luciana Guerra, Ana Flávia de Moraes Oliveira, Amanda Amaral Abrahão, Leticia Assad Maia Sandoval, Yure Rodrigues Araújo Martins, Maria Almirón, Fabiana Sherine Ganem dos Santos, Wildo Navegantes Araújo, Maria Regina Fernandes de Oliveira, and Henry Maia Peixoto. 2020. "Ten Epidemiological Parameters of COVID-19: Use of Rapid Literature Review to Inform Predictive Models During the Pandemic." *Frontiers in Public Health* 8 (December). <https://doi.org/10.3389/fpubh.2020.598547>.
- Ganem, Fabiana, Lucia Alonso, Andreu Colom-Cadena, Anna Bordas, Cinta Folch, Antoni Soriano-Arandes, and Jordi Casabona. 2023. "Syndromic Surveillance as a Predictive Tool for Health-Related School Absences in COVID-19 Sentinel Schools in Catalonia, Spain." Preprint. *Epidemiology*. <https://doi.org/10.1101/2023.03.24.23287681>.
- Ganem, Fabiana, Anna Bordas, Cinta Folch, Lucia Alonso, Marcos Montoro-Fernandez, Andreu Colom-Cadena, Ariadna Mas, et al. 2022. "The COVID-19 Sentinel Schools Network of Catalonia (CSSNC) Project: Associated Factors to Prevalence and Incidence of SARS-CoV-2 Infection in Educational Settings

- during the 2020–2021 Academic Year.” *PLOS ONE* 17 (11): e0277764. <https://doi.org/10.1371/journal.pone.0277764>.
- Ganem, Fabiana, Cinta Folch, Andreu Colom-Cadena, Anna Bordas, Lucia Alonso, Antoni Soriano-Arandes, Jordi Casabona, and on behalf of Sentinel School Network Study Group of Catalonia. 2023. “Determinants of COVID-19 Vaccine Hesitancy among Students and Parents in Sentinel Schools Network of Catalonia, Spain.” Edited by Harapan Harapan. *PLOS ONE* 18 (3): e0282871. <https://doi.org/10.1371/journal.pone.0282871>.
- Generalitat de Catalunya. 2022a. “Covid-19: Informació Estadística per al Seguiment de l’impacte de La Pandèmia.” Institut d’Estadística de Catalunya. <https://www.idescat.cat/>.
- . 2022b. “Dades Obertes i COVID-19.” https://governobert.gencat.cat/es/dades_obertes/dades-obertes-covid-19/.
- Generalitat de Catalunya. Departament de Salut. 2020. “Procediment d’actuació Enfront de Casos d’infecció Pel Nou Coronavirus SARS-CoV-2.” https://canalsalut.gencat.cat/web/.content/_A-Z/C/coronavirus-2019-ncov/material-.
- Generalitat de Catalunya. Departament d’Educació. 2020. “Gestió de Casos de COVID-19 Als Centres Educatius.”
- Goldstein, Edward, Marc Lipsitch, and Muge Cevik. 2021. “On the Effect of Age on the Transmission of SARS-CoV-2 in Households, Schools, and the Community.” *Journal of Infectious Diseases* 223 (3): 362–69. <https://doi.org/10.1093/infdis/jiaa691>.
- Golemis, Adrianos, Panteleimon Voitsidis, Eleni Parlapani, Vasiliki A Nikopoulou, Virginia Tsiropoulou, Panayiota Karamouzi, Aikaterini Giakoulidou, et al. 2022. “Young Adults’ Coping Strategies against Loneliness during the COVID-19-Related Quarantine in Greece.” *Health Promotion International* 37 (1): daab053. <https://doi.org/10.1093/heapro/daab053>.
- Grove, Christine, Alexandra Marinucci, and Ilaria Montagni. 2023. “Australian Youth Resilience and Help-Seeking during COVID-19: A Cross-Sectional Study.” *Behavioral Sciences* 13 (2): 121. <https://doi.org/10.3390/bs13020121>.
- Gurley, Stephen, Brady Bennett, Patrick Sullivan, Maryellen Kiley, Jamie Linde, David Szczerbacki, and Jodie Guest. 2021. “COVID-19 Vaccine Perceptions, Intentions, and Uptake: A Prospective College-Based Cohort Study (Preprint).” *JMIR Public Health and Surveillance*, December. <https://doi.org/10.2196/33739>.
- Halldorsdottir, Thorhildur, Ingibjorg Eva Thorisdottir, Caine C. A. Meyers, Bryndis Bjork Asgeirsdottir, Alfgeir Logi Kristjansson, Heiddis B. Valdimarsdottir, John P. Allegrante, and Inga Dora Sigfusdottir. 2021. “Adolescent Well-being amid the COVID-19 Pandemic: Are Girls Struggling More than Boys?” *JCPP Advances* 1 (2): e12027. <https://doi.org/10.1002/jcv2.12027>.
- Harris, Ross J., Jennifer A. Hall, Asad Zaidi, Nick J. Andrews, J. Kevin Dunbar, and Gavin Dabrera. 2021. “Effect of Vaccination on Household Transmission of SARS-CoV-2 in England.” *New England Journal of Medicine* 385 (8): 759–60. <https://doi.org/10.1056/NEJMc2107717>.
- Hassan, Sehar-un-Nisa, Fahad D. Algahtani, Mohammad Raafat Atteya, Ali A. Almishaal, Ahmed A. Ahmed, Sofian T. Obeidat, Reham Mohamed Kamel, and Rania Fathy Mohamed. 2021. “The Impact of Extended E-Learning on Emotional Well-Being of Students during the COVID-19 Pandemic in Saudi Arabia.” *Children* 9 (1): 13. <https://doi.org/10.3390/children9010013>.

- Hatami, Hossein, Mohsen Abbasi-Kangevari, Mohammad-Reza Malekpour, and Ali-Asghar Kolahi. 2021. "Knowledge, Attitudes, and Safety Practices About COVID-19 Among High School Students in Iran During the First Wave of the Pandemic." *Frontiers in Public Health* 9 (August). <https://doi.org/10.3389/fpubh.2021.680514>.
- Hellewell, Joel, Sam Abbott, Amy Gimma, Nikos I Bosse, Christopher I Jarvis, Timothy W Russell, James D Munday, et al. 2020. "Feasibility of Controlling COVID-19 Outbreaks by Isolation of Cases and Contacts." *The Lancet Global Health* 8 (4): e488–96. [https://doi.org/10.1016/S2214-109X\(20\)30074-7](https://doi.org/10.1016/S2214-109X(20)30074-7).
- Hoyt, Lindsay Till, Miranda P. Dotson, Ahna Ballonoff Suleiman, Natasha L. Burke, Jasmine B. Johnson, and Alison K. Cohen. 2023. "Internalizing the COVID-19 Pandemic: Gendered Differences in Youth Mental Health." *Current Opinion in Psychology* 52 (August): 101636. <https://doi.org/10.1016/j.copsyc.2023.101636>.
- Ibrahim, Nahla Khamis. 2020. "Epidemiologic Surveillance for Controlling Covid-19 Pandemic: Types, Challenges and Implications." *Journal of Infection and Public Health* 13 (11): 1630–38. <https://doi.org/10.1016/j.jiph.2020.07.019>.
- Im Kampe, Eveline Otte, Ann Sophie Lehfeld, Silke Buda, Udo Buchholz, and Walter Haas. 2020. "Surveillance of COVID-19 School Outbreaks, Germany, March to August 2020." *Eurosurveillance* 25 (38). <https://doi.org/10.2807/1560-7917.ES.2020.25.38.2001645>.
- Ingelbeen, Brecht, Laurène Peckeu, Marie Laga, Ilona Hendrix, Inge Neven, Marianne A.B. van der Sande, and Esther van Kleef. 2021. "Reducing Contacts to Stop SARS-CoV-2 Transmission during the Second Pandemic Wave in Brussels, Belgium, August to November 2020." *Eurosurveillance* 26 (7). <https://doi.org/10.2807/1560-7917.ES.2021.26.7.2100065>.
- Islam, Md. Saiful, Abu Bakkar Siddique, Rejina Akter, Rafia Tasnim, Md. Safaet Hossain Sujon, Paul R. Ward, and Md. Tajuddin Sikder. 2021. "Knowledge, Attitudes and Perceptions towards COVID-19 Vaccinations: A Cross-Sectional Community Survey in Bangladesh." *BMC Public Health* 21 (1): 1851. <https://doi.org/10.1186/s12889-021-11880-9>.
- Ismail, Sharif A, Vanessa Saliba, Jamie Lopez Bernal, Mary E Ramsay, and Shamez N Ladhani. 2021. "SARS-CoV-2 Infection and Transmission in Educational Settings: A Prospective, Cross-Sectional Analysis of Infection Clusters and Outbreaks in England." *The Lancet Infectious Diseases* 21 (3): 344–53. [https://doi.org/10.1016/S1473-3099\(20\)30882-3](https://doi.org/10.1016/S1473-3099(20)30882-3).
- Jeong, Darae, Chang Hyeong Lee, Yongho Choi, and Junseok Kim. 2016. "The Daily Computed Weighted Averaging Basic Reproduction Number R_0 , k , ω , n for MERS-CoV in South Korea." *Physica A: Statistical Mechanics and Its Applications* 451 (June): 190–97. <https://doi.org/10.1016/j.physa.2016.01.072>.
- Jorge, D C P, J F Oliveira, J G V Miranda, R F S Andrade, and S T R Pinho. 2022. "Estimating the Effective Reproduction Number for Heterogeneous Models Using Incidence Data." <https://doi.org/10.1098/rsos.220005>.
- Julieta Politi, Mario Martín-Sánchez, Lilas Mercuriali, Blanca Borrás-Bermejo, Joaquín López-Contreras, Anna Vilella, Judit Villar, et al. 2021. "Epidemiological Characteristics and Outcomes of COVID-19 Cases: Mortality Inequalities by Socioeconomic Status, Barcelona, Spain, 24 February to 4 May 2020." *Eurosurveillance* 26 (20). <https://doi.org/10.2807/1560-7917>.
- Kang, Sifan, Yuliang Sun, Xinxin Zhang, Fangjun Sun, Bingqi Wang, and Wenfei Zhu. 2020. "Is Physical Activity Associated with Mental Health among Chinese

- Adolescents during Isolation in COVID-19 Pandemic?:" *Journal of Epidemiology and Global Health* 11 (1): 26. <https://doi.org/10.2991/jegh.k.200908.001>.
- Kauhanen, Laura, Wan Mohd Azam Wan Mohd Yunus, Lotta Lempinen, Kirsi Peltonen, David Gyllenberg, Kaisa Mishina, Sonja Gilbert, Kalpana Bastola, June S. L. Brown, and Andre Sourander. 2023. "A Systematic Review of the Mental Health Changes of Children and Young People before and during the COVID-19 Pandemic." *European Child & Adolescent Psychiatry* 32 (6): 995–1013. <https://doi.org/10.1007/s00787-022-02060-0>.
- Keeling, Matt J., Michael J. Tildesley, Benjamin D. Atkins, Bridget Penman, Emma Southall, Glen Guyver-Fletcher, Alex Holmes, et al. 2021. "The Impact of School Reopening on the Spread of COVID-19 in England." *Philosophical Transactions of the Royal Society B: Biological Sciences* 376 (1829). <https://doi.org/10.1098/rstb.2020.0261>.
- Kilbourne, Edwin D. 2006. "Influenza Pandemics of the 20th Century." *Emerging Infectious Diseases* 12 (1): 9–14. <https://doi.org/10.3201/eid1201.051254>.
- Kim, Soyoun, Yae-Jean Kim, Kyong Ran Peck, and Eunok Jung. 2020. "School Opening Delay Effect on Transmission Dynamics of Coronavirus Disease 2019 in Korea: Based on Mathematical Modeling and Simulation Study." *Journal of Korean Medical Science* 35 (13). <https://doi.org/10.3346/jkms.2020.35.e143>.
- Kirsten, Carolin, Manja Unrath, Christian Lück, Alexander H Dalpke, Reinhard Berner, and Jakob Armann. 2021. "SARS-CoV-2 Seroprevalence in Students and Teachers: A Longitudinal Study from May to October 2020 in German Secondary Schools." *BMJ Open* 11: 49876. <https://doi.org/10.1136/bmjopen-2021-049876>.
- Knight, Julia A, Rebecca D Kehm, Lisa Schwartz, Caren J Frost, Wendy K Chung, Sarah Colonna, Theresa H M Keegan, et al. 2021. "Prepubertal Internalizing Symptoms and Timing of Puberty Onset in Girls." *American Journal of Epidemiology* 190 (3): 431–38. <https://doi.org/10.1093/aje/kwaa223>.
- Kriemler, Susi, Agne Ulyte, Priska Ammann, Gabriela P. Peralta, Christoph Berger, Milo A. Puhan, and Thomas Radtke. 2021. "Surveillance of Acute SARS-CoV-2 Infections in School Children and Point-Prevalence During a Time of High Community Transmission in Switzerland." *Frontiers in Pediatrics* 9 (March). <https://doi.org/10.3389/fped.2021.645577>.
- Krishnaratne, Shari, Lisa M Padenhauer, Michaela Coenen, Karin Geffert, Caroline Jung-Sievers, Carmen Klinger, Suzie Kratzer, et al. 2020. "Measures Implemented in the School Setting to Contain the COVID-19 Pandemic: A Rapid Scoping Review." *Cochrane Database of Systematic Reviews* 2020 (12). <https://doi.org/10.1002/14651858.CD013812>.
- Kyei-Arthur, Frank, Sylvester Kyei-Gyamfi, Martin Wiredu Agyekum, Grace Frempong Afrifa-Anane, and Bernard Akyeampong Amoh. 2022. "Parents' and Guardians' Acceptability of COVID-19 Vaccination for Children in Ghana: An Online Survey." *PloS One* 17 (8): e0272801. <https://doi.org/10.1371/journal.pone.0272801>.
- Lai, Jennifer, Helen E Hughes, Roger Morbey, Paul Loveridge, Jamie Lopez Bernal, Vanessa Saliba, Esther Kissling, Alex Lovelock-Wren, Jeremy Mabbitt, and Alex J Elliot. 2021. "Epidemiology and Infection Developing a Sentinel Syndromic Surveillance System Using School-Absenteeism Data, Example Monitoring Absences over the 2020 COVID-19 Pandemic." *Epidemiology and Infection* 149. <https://doi.org/10.1017/S0950268821002399>.
- Lin, Jessica A., Sara F. Forman, Carly Milliren, Julia Vitagliano, Rebecca Spigel, Elizabeth R. Woods, and Tracy K. Richmond. 2021. "Eating Disorder Recovery:

- The Relationship Between Malnutrition and Symptoms of Anxiety/Depression in Youth With Restrictive Eating Disorders.” *Journal of Adolescent Health* 68 (2): S52–53. <https://doi.org/10.1016/j.jadohealth.2020.12.108>.
- Liu, Y., Q. Ma, H. Liu, and Z. Guo. 2022. “Public Attitudes and Influencing Factors toward COVID-19 Vaccination for Adolescents/Children: A Scoping Review.” *Public Health* 205 (April): 169–81. <https://doi.org/10.1016/j.puhe.2022.02.002>.
- Llupià, Anna, Alícia Borràs-Santos, Caterina Guinovart, Mireia Utzet, David Moríña, and Joaquim Puig. 2021. “SARS-CoV-2 Transmission in Students of Public Schools of Catalonia (Spain) after a Month of Reopening.” *PLOS ONE* 16 (5): e0251593. <https://doi.org/10.1371/journal.pone.0251593>.
- Lo Moro, Giuseppina, Tiziana Sinigaglia, Fabrizio Bert, Armando Savatteri, Maria Rosaria Gualano, and Roberta Siliquini. 2020. “Reopening Schools during the COVID-19 Pandemic: Overview and Rapid Systematic Review of Guidelines and Recommendations on Preventive Measures and the Management of Cases.” *International Journal of Environmental Research and Public Health* 17 (23): 1–21. <https://doi.org/10.3390/ijerph17238839>.
- López-Bueno, Rubén, Guillermo F. López-Sánchez, José A. Casajús, Joaquín Calatayud, Mark A. Tully, and Lee Smith. 2021. “Potential Health-Related Behaviors for Pre-School and School-Aged Children during COVID-19 Lockdown: A Narrative Review.” *Preventive Medicine* 143 (February). <https://doi.org/10.1016/j.ypmed.2020.106349>.
- Lugon, amella, Trevon Fuller, Luana Damasceno, Guilherme Calvet, Paola Cristina Resende, Aline Rocha Matos, Tulio Machado Fumian, et al. 2021. “SARS-CoV-2 Infection Dynamics in Children and Household Contacts in a Slum in Rio de Janeiro ARTICLE.” *Pediatrics* 148 (1): 2021050182. <https://doi.org/10.1542/peds.2021-050182>.
- Macartney, Kristine, Helen E. Quinn, Alexis J. Pillsbury, Archana Koirala, Lucy Deng, Noni Winkler, Anthea L. Katelaris, et al. 2020. “Transmission of SARS-CoV-2 in Australian Educational Settings: A Prospective Cohort Study.” *The Lancet Child and Adolescent Health* 4 (11): 807–16. [https://doi.org/10.1016/S2352-4642\(20\)30251-0](https://doi.org/10.1016/S2352-4642(20)30251-0).
- Magson, Natasha R., Justin Y. A. Freeman, Ronald M. Rapee, Cele E. Richardson, Ella L. Oar, and Jasmine Fardouly. 2021. “Risk and Protective Factors for Prospective Changes in Adolescent Mental Health during the COVID-19 Pandemic.” *Journal of Youth and Adolescence* 50 (1): 44–57. <https://doi.org/10.1007/s10964-020-01332-9>.
- Manivannan, Madhumitha, Manasi P Jogalekar, Muthu Subash Kavitha, Balu Alagar Venmathi Maran, and Prakash Gangadaran. 2021. “A Mini-Review on the Effects of COVID-19 on Younger Individuals.” *Experimental Biology and Medicine* 246 (3): 293–97. <https://doi.org/10.1177/1535370220975118>.
- Marco-Ahulló, Adrià, Israel Villarrasa-Sapiña, and Gonzalo Monfort-Torres. 2021. “Estudio Descriptivo Sobre Las Diferencias de Género En El Estrés Académico Derivado Del Contexto COVID-19 En Población Universitaria Española (Descriptive Study on Gender Differences in Academic Stress Derived from the COVID-19 Context in a Spanish Unive.” *Retos* 43 (September): 845–51. <https://doi.org/10.47197/retos.v43i0.88968>.
- Marí-Dell’Olmo, Marc, Mercè Gotsens, M Isabel Pasarín, Maica Rodríguez-Sanz, Lucía Artazcoz, Patricia Garcia de Olalla, Cristina Rius, and Carme Borrell. 2021. “Socioeconomic Inequalities in COVID-19 in a European Urban Area: Two

- Waves, Two Patterns.” *International Journal of Environmental Research and Public Health* 18 (3): 1256. <https://doi.org/10.3390/ijerph18031256>.
- Marks, Michael, Pere Millat-Martinez, Dan Ouchi, Chrissy h. Roberts, Andrea Alemany, Marc Corbacho-Monné, Maria Ubals, et al. 2021. “Transmission of COVID-19 in 282 Clusters in Catalonia, Spain: A Cohort Study.” *The Lancet Infectious Diseases* 21 (5): 629–36. [https://doi.org/10.1016/S1473-3099\(20\)30985-3/ATTACHMENT/59270188-9308-4D12-9A13-4C1F5A58D3BB/MMC2.PDF](https://doi.org/10.1016/S1473-3099(20)30985-3/ATTACHMENT/59270188-9308-4D12-9A13-4C1F5A58D3BB/MMC2.PDF).
- McKee, Chephra, and Kristin Bohannon. 2016. “Exploring the Reasons Behind Parental Refusal of Vaccines.” *The Journal of Pediatric Pharmacology and Therapeutics* 21 (2): 104–9. <https://doi.org/10.5863/1551-6776-21.2.104>.
- Mena, Gonzalo E., Pamela P. Martinez, Ayesha S. Mahmud, Pablo A. Marquet, Caroline O. Buckee, and Mauricio Santillana. 2021. “Socioeconomic Status Determines COVID-19 Incidence and Related Mortality in Santiago, Chile.” *Science* 372 (6545). <https://doi.org/10.1126/science.abg5298>.
- Molero Jurado, María Del Mar, María Del Carmen Pérez-Fuentes, Elena Fernández-Martínez, África Martos Martínez, and José Jesús Gázquez Linares. 2021. “Coping Strategies in the Spanish Population: The Role in Consequences of COVID-19 on Mental Health.” *Frontiers in Psychiatry* 12 (April): 606621. <https://doi.org/10.3389/fpsy.2021.606621>.
- Moore, Sam, Edward M Hill, Michael J Tildesley, Louise Dyson, and Matt J Keeling. 2021. “Vaccination and Non-Pharmaceutical Interventions for COVID-19: A Mathematical Modelling Study.” *The Lancet Infectious Diseases* 21 (6): 793–802. [https://doi.org/10.1016/S1473-3099\(21\)00143-2](https://doi.org/10.1016/S1473-3099(21)00143-2).
- Munday, James D., Christopher I. Jarvis, Amy Gimma, Kerry L.M. Wong, Kevin van Zandvoort, Yang Liu, Joel Hellewell, et al. 2021. “Estimating the Impact of Reopening Schools on the Reproduction Number of SARS-CoV-2 in England, Using Weekly Contact Survey Data.” *BMC Medicine* 19 (1). <https://doi.org/10.1186/s12916-021-02107-0>.
- Nazeem Muhajarine, Daniel A Adeyinka, Jessica Mccutcheon, Kathryn L Green, Miles Fahlman Id, and Natalie Kallio Id. 2021. “COVID-19 Vaccine Hesitancy and Refusal and Associated Factors in an Adult Population in Saskatchewan, Canada: Evidence from Predictive Modelling.” <https://doi.org/10.1371/journal.pone.0259513>.
- Nearchou, Finiki, Clodagh Flinn, Rachel Niland, Sheena Siva Subramaniam, and Eilis Hennessy. 2020. “Exploring the Impact of COVID-19 on Mental Health Outcomes in Children and Adolescents: A Systematic Review.” *International Journal of Environmental Research and Public Health* 17 (22): 8479. <https://doi.org/10.3390/ijerph17228479>.
- Nguyen, Trung, Mehnaz Adnan, Binh P Nguyen, Joep de Ligt, Jemma L Geoghegan, Richard Dean, Sarah Jefferies, et al. 2021. “COVID-19 Vaccine Strategies for Aotearoa New Zealand: A Mathematical Modelling Study.” *The Lancet Regional Health - Western Pacific* 15 (October): 100256. <https://doi.org/10.1016/j.lanwpc.2021.100256>.
- Oboho, Ikwo K., Sara M. Tomczyk, Ahmad M. Al-Asmari, Ayman A. Banjar, Hani Al-Mugti, Muhannad S. Aloraini, Khulud Z. Alkhalidi, et al. 2015. “2014 MERS-CoV Outbreak in Jeddah — A Link to Health Care Facilities.” *New England Journal of Medicine* 372 (9): 846–54. <https://doi.org/10.1056/NEJMoa1408636>.
- Olusanya, Olufunto A, Robert A Bednarczyk, Robert L Davis, Arash Shaban-Nejad, Viviana Moschese, Baldassarre Martire, Raffaele Dimiccoli Hospital, Italy Srinivasa, and Reddy Bonam. 2021. “Addressing Parental Vaccine Hesitancy and

- Other Barriers to Childhood/Adolescent Vaccination Uptake During the Coronavirus (COVID-19) Pandemic.” *Article* 12: 1. <https://doi.org/10.3389/fimmu.2021.663074>.
- Orgilés, Mireia, Alexandra Morales, Elisa Delvecchio, Claudia Mazzeschi, and José P. Espada. 2020. “Immediate Psychological Effects of the COVID-19 Quarantine in Youth From Italy and Spain.” *Frontiers in Psychology* 11 (November): 579038. <https://doi.org/10.3389/fpsyg.2020.579038>.
- Pacella-LaBarbara, Maria L., Yunseo Linda Park, P. Daniel Patterson, Ankur Doshi, Maria Koenig Guyette, Ambrose H. Wong, Bernard P. Chang, and Brian P. Suffoletto. 2021. “COVID-19 Vaccine Uptake and Intent Among Emergency Healthcare Workers: A Cross-Sectional Survey.” *Journal of Occupational and Environmental Medicine* 63 (10): 852–56. <https://doi.org/10.1097/JOM.0000000000002298>.
- Park, Young Joon, Young June Choe, Ok Park, Shin Young Park, Young-Man Kim, Jieun Kim, Sanghui Kweon, et al. 2020. “Contact Tracing during Coronavirus Disease Outbreak, South Korea, 2020.” *Emerging Infectious Diseases* 26 (10): 2465–68. <https://doi.org/10.3201/eid2610.201315>.
- Pascoe, Michaela, Alan P Bailey, Melinda Craike, Tim Carter, Rhiannon Patten, Nigel Stepto, and Alexandra Parker. 2020. “Physical Activity and Exercise in Youth Mental Health Promotion: A Scoping Review.” *BMJ Open Sport & Exercise Medicine* 6 (1): e000677. <https://doi.org/10.1136/bmjsem-2019-000677>.
- Pei, Sen, Xian Teng, Paul Lewis, and Jeffrey Shaman. 2021. “Optimizing Respiratory Virus Surveillance Networks Using Uncertainty Propagation.” *Nature Communications* 12 (1): 222. <https://doi.org/10.1038/s41467-020-20399-3>.
- Perramon, Aida, Antoni Soriano-Arandes, David Pino, Uxue Lazcano, Cristina Andrés, Martí Català, Anna Gatell, et al. 2021. “Schools as a Framework for COVID-19 Epidemiological Surveillance of Children in Catalonia, Spain: A Population-Based Study.” *Frontiers in Pediatrics* 9 (September). <https://doi.org/10.3389/fped.2021.754744>.
- Pigaiani, Yolande, Leonardo Zoccante, Anastasia Zocca, Athos Arzenton, Marco Menegolli, Sabrina Fadel, Mirella Ruggeri, and Marco Colizzi. 2020. “Adolescent Lifestyle Behaviors, Coping Strategies and Subjective Wellbeing during the COVID-19 Pandemic: An Online Student Survey.” *Healthcare* 8 (4): 472. <https://doi.org/10.3390/healthcare8040472>.
- Pinilla, Jaime, and Alejandro Rodriguez-Caro. 2019. “Differences in Healthcare Utilisation between Users and Non-Users of Homeopathic Products in Spain: Results from Three Waves of the National Health Survey (2011-2017).” *PLOS ONE* 14 (5): e0216707. <https://doi.org/10.1371/journal.pone.0216707>.
- Pollán, Marina, Beatriz Pérez-Gómez, Roberto Pastor-Barriuso, Jesús Oteo, Miguel A Hernán, Mayte Pérez-Olmeda, Jose L Sanmartín, et al. 2020. “Prevalence of SARS-CoV-2 in Spain (ENE-COVID): A Nationwide, Population-Based Seroepidemiological Study.” *The Lancet* 396 (10250): 535–44. [https://doi.org/10.1016/S0140-6736\(20\)31483-5](https://doi.org/10.1016/S0140-6736(20)31483-5).
- Potter, C.W. 2001. “A History of Influenza.” *Journal of Applied Microbiology* 91 (4): 572–79. <https://doi.org/10.1046/j.1365-2672.2001.01492.x>.
- Qin, Chenyuan, Ruitong Wang, Liyuan Tao, Min Liu, and Jue Liu. 2022. “Association Between Risk Perception and Acceptance for a Booster Dose of COVID-19 Vaccine to Children Among Child Caregivers in China.” *Frontiers in Public Health* 10: 834572. <https://doi.org/10.3389/fpubh.2022.834572>.

- Rees, Franziska, Mattis Geiger, Lau Lilleholt, Ingo Zettler, Cornelia Betsch, Robert Böhm, and Oliver Wilhelm. 2022. “Measuring Parents’ Readiness to Vaccinate Themselves and Their Children against COVID-19.” *Vaccine* 40 (28): 3825–34. <https://doi.org/10.1016/j.vaccine.2022.04.091>.
- Rella, Simon A., Yuliya A. Kulikova, Emmanouil T. Dermitzakis, and Fyodor A. Kondrashov. 2021. “Rates of SARS-CoV-2 Transmission and Vaccination Impact the Fate of Vaccine-Resistant Strains.” *Scientific Reports* 11 (1): 15729. <https://doi.org/10.1038/s41598-021-95025-3>.
- Riazi, Negin A., Katelyn Battista, Markus J. Duncan, Terrance J. Wade, William Pickett, Mark A. Ferro, Scott T. Leatherdale, and Karen A. Patte. 2023. “Stronger Together: Coping Behaviours and Mental Health Changes of Canadian Adolescents in Early Phases of the COVID-19 Pandemic.” *BMC Public Health* 23 (1): 319. <https://doi.org/10.1186/s12889-023-15249-y>.
- Riou, Julien, Radoslaw Panczak, Christian L. Althaus, Christoph Junker, Damir Perisa, Katrin Schneider, Nicola G. Criscuolo, Nicola Low, and Matthias Egger. 2021. “Socioeconomic Position and the COVID-19 Care Cascade from Testing to Mortality in Switzerland: A Population-Based Analysis.” *The Lancet Public Health* 6 (9): e683–91. [https://doi.org/10.1016/S2468-2667\(21\)00160-2](https://doi.org/10.1016/S2468-2667(21)00160-2).
- RNVE. 2023. “Situación de COVID-19 En España. Informe N° 178.” 178. Spain: Red Nacional de Vigilancia Epidemiológica.
- Rogés, Judit, Marina Bosque-Prous, Joan Colom, Cinta Folch, Tivy Barón-Garcia, Helena González-Casals, Esteve Fernández, and Albert Espelt. 2021. “Consumption of Alcohol, Cannabis, and Tobacco in a Cohort of Adolescents before and during COVID-19 Confinement.” *International Journal of Environmental Research and Public Health* 18 (15): 7849. <https://doi.org/10.3390/ijerph18157849>.
- Romano, Isabella, Karen A. Patte, Margaret De Groh, Ying Jiang, Terrance J. Wade, Richard E. Bélanger, and Scott T. Leatherdale. 2021. “Substance-Related Coping Behaviours among Youth during the Early Months of the COVID-19 Pandemic.” *Addictive Behaviors Reports* 14 (December): 100392. <https://doi.org/10.1016/j.abrep.2021.100392>.
- Saulle, Rosella, Manuela De Sario, Antonella Bena, Paola Capra, Martina Culasso, Marina Davoli, Aurelia De Lorenzo, et al. 2022. “School Closures and Mental Health, Wellbeing and Health Behaviours among Children and Adolescents during the Second COVID-19 Wave: A Systematic Review of the Literature.” *Epidemiologia e Prevenzione* 46 (5–6): 333–52. <https://doi.org/10.19191/EP22.5-6.A542.089>.
- Schmit, Kathryn M., Roger Brown, Supriya Hayer, Mary M. Checovich, James E. Gern, Ellen R. Wald, and Bruce Barrett. 2021. “Wisconsin Upper Respiratory Symptom Survey for Kids: Validation of an Illness-Specific Quality of Life Instrument.” *Pediatric Research* 90 (6): 1207–14. <https://doi.org/10.1038/s41390-021-01395-9>.
- Shen, Zhong Hua, Yu Ming Chu, Muhammad Altaf Khan, Shabbir Muhammad, Omar A. Al-Hartomy, and M. Higazy. 2021. “Mathematical Modeling and Optimal Control of the COVID-19 Dynamics.” *Results in Physics* 31 (December). <https://doi.org/10.1016/j.rinp.2021.105028>.
- Solís Arce, Julio S., Shana S. Warren, Niccolò F. Meriggi, Alexandra Scacco, Nina McMurry, Maarten Voors, Georgiy Syunyaev, et al. 2021. “COVID-19 Vaccine Acceptance and Hesitancy in Low- and Middle-Income Countries.” *Nature Medicine* 27 (8): 1385–94. <https://doi.org/10.1038/s41591-021-01454-y>.

- Sonabend, Raphael, Lilith K Whittles, Natsuko Imai, Pablo N Perez-Guzman, Edward S Knock, Thomas Rawson, Katy A M Gaythorpe, et al. 2021. “Non-Pharmaceutical Interventions, Vaccination, and the SARS-CoV-2 Delta Variant in England: A Mathematical Modelling Study.” *The Lancet* 398 (10313): 1825–35. [https://doi.org/10.1016/S0140-6736\(21\)02276-5](https://doi.org/10.1016/S0140-6736(21)02276-5).
- Soriano-Arandes, Antoni, Anna Gatell, Pepe Serrano, Mireia Biosca, Ferran Campillo, Ramon Capdevila, Anna Fàbrega, et al. 2021. “Household Severe Acute Respiratory Syndrome Coronavirus 2 Transmission and Children: A Network Prospective Study.” *Clinical Infectious Diseases : An Official Publication of the Infectious Diseases Society of America* 73 (6): e1261–69. <https://doi.org/10.1093/CID/CIAB228>.
- Steinert, Janina I., Henrike Sternberg, Hannah Prince, Barbara Fasolo, Matteo M. Galizzi, Tim Bütthe, and Giuseppe A. Veltri. 2022. “COVID-19 Vaccine Hesitancy in Eight European Countries: Prevalence, Determinants, and Heterogeneity.” *Science Advances* 8 (17): 9825. <https://doi.org/10.1126/SCIADV.ABM9825>.
- Tang, Suqin, Mi Xiang, Teris Cheung, and Yu-Tao Xiang. 2021. “Mental Health and Its Correlates among Children and Adolescents during COVID-19 School Closure: The Importance of Parent-Child Discussion.” *Journal of Affective Disorders* 279 (January): 353–60. <https://doi.org/10.1016/j.jad.2020.10.016>.
- Theberath, Monique, David Bauer, Weizhi Chen, Manisha Salinas, Arya B. Mohabbat, Juan Yang, Tony Y. Chon, Brent A. Bauer, and Dietlind L. Wahner-Roedler. 2022. “Effects of COVID-19 Pandemic on Mental Health of Children and Adolescents: A Systematic Review of Survey Studies.” *SAGE Open Medicine* 10: 20503121221086712. <https://doi.org/10.1177/20503121221086712>.
- Tönshoff, Burkhard, Barbara Müller, Roland Elling, Hanna Renk, Peter Meissner, Hartmut Hengel, Sven F. Garbade, et al. 2021. “Prevalence of SARS-CoV-2 Infection in Children and Their Parents in Southwest Germany.” *JAMA Pediatrics* 175 (6): 586. <https://doi.org/10.1001/jamapediatrics.2021.0001>.
- Tormos, Raül, Pau Fonseca I Casas, and Josep Maria Garcia-Alamino. 2022. “In-Person School Reopening and the Spread of SARS-CoV-2 during the Second Wave in Spain.” *Frontiers in Public Health* 10: 990277. <https://doi.org/10.3389/fpubh.2022.990277>.
- Tzur Bitan, Dana, Ariella Grossman-Giron, Yuval Bloch, Yael Mayer, Noga Shiffman, and Shlomo Mendlovic. 2020. “Fear of COVID-19 Scale: Psychometric Characteristics, Reliability and Validity in the Israeli Population.” *Psychiatry Research* 289 (July): 113100. <https://doi.org/10.1016/j.psychres.2020.113100>.
- Van Den Driessche, P., and James Watmough. 2002. “Reproduction Numbers and Sub-Threshold Endemic Equilibria for Compartmental Models of Disease Transmission.” *Mathematical Biosciences* 180 (1–2): 29–48. [https://doi.org/10.1016/S0025-5564\(02\)00108-6](https://doi.org/10.1016/S0025-5564(02)00108-6).
- Van Loon, Welmoed, Stefanie Theuring, Franziska Hommes, Marcus A. Mall, Joachim Seybold, Tobias Kurth, and Frank P. Mockenhaupt. 2021. “Prevalence of SARS-CoV-2 Infections among Students, Teachers, and Household Members during Lockdown and Split Classes in Berlin, Germany.” *JAMA Network Open*. <https://doi.org/10.1001/jamanetworkopen.2021.27168>.
- Varia, Monali, Samantha Wilson, Shelly Sarwal, Allison McGeer, Effie Gournis, Eleni Galanis, Bonnie Henry, and Hospital Outbreak Investigation Team. 2003. “Investigation of a Nosocomial Outbreak of Severe Acute Respiratory Syndrome (SARS) in Toronto, Canada.” *CMAJ: Canadian Medical Association Journal = Journal de l'Association Medicale Canadienne* 169 (4): 285–92.

- Viner, Russell M., Oliver T. Mytton, Chris Bonell, G. J. Melendez-Torres, Joseph Ward, Lee Hudson, Claire Waddington, et al. 2021. "Susceptibility to SARS-CoV-2 Infection among Children and Adolescents Compared with Adults: A Systematic Review and Meta-Analysis." *JAMA Pediatrics* 175 (2): 143–56. <https://doi.org/10.1001/jamapediatrics.2020.4573>.
- Viswanath, K., Mesfin Bekalu, Dhriti Dhawan, Ramya Pinnamaneni, Jenna Lang, and Rachel McCloud. 2021. "Individual and Social Determinants of COVID-19 Vaccine Uptake." *BMC Public Health* 21 (1). <https://doi.org/10.1186/s12889-021-10862-1>.
- Voysey, Merryn, Sue Ann Costa Clemens, Shabir A Madhi, Lily Y Weckx, Pedro M Folegatti, Parvinder K Aley, Brian Angus, et al. 2021. "Safety and Efficacy of the ChAdOx1 nCoV-19 Vaccine (AZD1222) against SARS-CoV-2: An Interim Analysis of Four Randomised Controlled Trials in Brazil, South Africa, and the UK." *The Lancet* 397 (10269): 99–111. [https://doi.org/10.1016/S0140-6736\(20\)32661-1](https://doi.org/10.1016/S0140-6736(20)32661-1).
- Wallinga, J. 2004. "Different Epidemic Curves for Severe Acute Respiratory Syndrome Reveal Similar Impacts of Control Measures." *American Journal of Epidemiology* 160 (6): 509–16. <https://doi.org/10.1093/aje/kwh255>.
- Wallinga, J, and M Lipsitch. 2007. "How Generation Intervals Shape the Relationship between Growth Rates and Reproductive Numbers." *Proceedings of the Royal Society B: Biological Sciences* 274 (1609): 599–604. <https://doi.org/10.1098/rspb.2006.3754>.
- Wallinga, Jacco, and Peter Teunis. 2004. "Different Epidemic Curves for Severe Acute Respiratory Syndrome Reveal Similar Impacts of Control Measures." *American Journal of EPIDEMIOLOGY*. Vol. 160. <https://academic.oup.com/aje/article/160/6/509/79472>.
- Watson, Oliver J, Gregory Barnsley, Jaspreet Toor, Alexandra B Hogan, Peter Winskill, and Azra C Ghani. 2022. "Global Impact of the First Year of COVID-19 Vaccination: A Mathematical Modelling Study." *The Lancet Infectious Diseases* 22 (9): 1293–1302. [https://doi.org/10.1016/S1473-3099\(22\)00320-6](https://doi.org/10.1016/S1473-3099(22)00320-6).
- WHO. 2023. "Statement on the Fifteenth Meeting of the IHR (2005) Emergency Committee on the COVID-19 Pandemic." Institutional website. www.who.int. January 5, 2023. [https://www.who.int/news/item/05-05-2023-statement-on-the-fifteenth-meeting-of-the-international-health-regulations-\(2005\)-emergency-committee-regarding-the-coronavirus-disease-\(covid-19\)-pandemic](https://www.who.int/news/item/05-05-2023-statement-on-the-fifteenth-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-coronavirus-disease-(covid-19)-pandemic).
- WHO, . World Health Organization. 2020. "Survey Tool and Guidance: Rapid, Simple, Flexible Behavioural Insights on COVID-19." World Health Organization. Regional Office for Europe. <https://apps.who.int/iris/handle/10665/333549>.
- Wolf, Kristin, and Julian Schmitz. 2023. "Scoping Review: Longitudinal Effects of the COVID-19 Pandemic on Child and Adolescent Mental Health." *European Child & Adolescent Psychiatry*, April, 1–56. <https://doi.org/10.1007/s00787-023-02206-8>.
- Wong, Martin C.S., Eliza L.Y. Wong, Junjie Huang, Annie W.L. Cheung, Kevin Law, Marc K.C. Chong, Rita W.Y. Ng, et al. 2021. "Acceptance of the COVID-19 Vaccine Based on the Health Belief Model: A Population-Based Survey in Hong Kong." *Vaccine* 39 (7): 1148–56. <https://doi.org/10.1016/j.vaccine.2020.12.083>.
- World Health Organization. 2020a. "Novel Coronavirus (2019-nCoV) Situation Report - 17." *WHO Bulletin*.

- . 2020b. “Pneumonia of Unknown Cause – China.” *Disease Outbreak News*. 2020. <https://www.who.int/csr/don/05-january-2020-pneumonia-of-unknown-cause-china/en/>.
- . n.d. “Novel Coronavirus (2019-nCoV) Situation Reports.” <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports>.
- World Health Organization (WHO). 2020. “Novel Coronavirus (2019-nCoV).” *WHO Bulletin*, no. JANUARY: 1–7.
- Yamey, Gavin, Patricia Garcia, Fatima Hassan, Wenhui Mao, Kaci Kennedy McDade, Madhukar Pai, Senjuti Saha, Philip Schellekens, Andrea Taylor, and Krishna Udayakumar. 2022. “It Is Not Too Late to Achieve Global Covid-19 Vaccine Equity.” *BMJ*, March, e070650. <https://doi.org/10.1136/bmj-2022-070650>.
- Yi, Seonju, Young-Man Kim, Young June Choe, Seonhee Ahn, Sohee Han, and Young-Joon Park. 2021. “Geospatial Analysis of Age-Specific SARS-CoV-2 Transmission Patterns in Households, Korea.” *Journal of Korean Medical Science* 36 (8). <https://doi.org/10.3346/jkms.2021.36.e63>.
- Zhang, Juanjuan, Maria Litvinova, Yuxia Liang, Yan Wang, Wei Wang, Shanlu Zhao, Qianhui Wu, et al. 2020. “Changes in Contact Patterns Shape the Dynamics of the COVID-19 Outbreak in China.” *Science* 368 (6498): 1481–86. <https://doi.org/10.1126/science.abb8001>.
- Zhong, Ns, Bj Zheng, Ym Li, Llm Poon, Zh Xie, Kh Chan, Ph Li, et al. 2003. “Epidemiology and Cause of Severe Acute Respiratory Syndrome (SARS) in Guangdong, People’s Republic of China, in February, 2003.” *The Lancet* 362 (9393): 1353–58. [https://doi.org/10.1016/S0140-6736\(03\)14630-2](https://doi.org/10.1016/S0140-6736(03)14630-2).
- Zimmerman, Kanecia O., Ibukunoluwa C. Akinboyo, M. Alan Brookhart, Angelique E. Boutzoukas, Kathleen A. McGann, Michael J. Smith, Gabriela Maradiaga Panayotti, et al. 2021. “Incidence and Secondary Transmission of SARS-CoV-2 Infections in Schools.” *Pediatrics* 147 (4): e2020048090. <https://doi.org/10.1542/peds.2020-048090>.

DISCUSSION

The occurrence of SARS-CoV-2 in CSSNC educational settings

The social effect of school closures on young people and families is a controversial issue. In one aspect, there is concern about preventing the transmission of SARS-CoV-2, but several important gaps in the educational process and child care have also been identified. (Tormos, Fonseca I Casas, and Garcia-Alamino 2022). Our results indicated that transmission in the school environment did not appear to contribute much to the spread of the virus, especially for younger children, and this findings support the decision to keep schools open while following several public health measures and safety protocols to control the transmission of the virus were implemented, as other studies that pointed the same conclusion (Soriano-Arandes et al. 2021; Kriemler et al. 2021; Ertem et al. 2021).

A populational study carried out at Catalonia with children under 18 years found a seroprevalence of 4.4% between March and April 2020 (Pollán et al. 2020), lower than what we found in the CSSNC. This difference may reflect the difficulty of diagnosing asymptomatic youngers especially during the initial period of the pandemic, emphasizing the importance of active surveillance of school sentinel populations, for the timely detection of respiratory viruses, although, the detection of active SARS-CoV-2 infections in CSSNC was lower than Catalonia during the same period (Generalitat de Catalunya 2022b; Perramon et al. 2021; Llupià et al. 2021; Pollán et al. 2020). These low rates of SARS-CoV-2 infections founded in our longitudinal were, consistent with other studies that have very similar results to ours (Kirsten et al. 2021; Choe et al. 2021; Tönshoff et al. 2021; Van Loon et al. 2021).

As expected, in our study there was a significant increase in SARS-CoV-2 seroprevalence in the school staff group, which can be explained by the increase of vaccination coverage.

Demographic and economic aspects are described in previous studies as determinants in the virus transmission (Lugon et al. 2021; Mena et al. 2021; Riou et al. 2021). In our study, we found correlations between these determinants and SARS-CoV-2 infection, however these results were dependent of the pandemic period. At the beginning a improved economic situation was positively associated with infections, in the subsequent waves, we observed a new trend where a higher infection risk was associated with lower economic status. This provides important clues to understanding the COVID-19 burden in economic and demographic contexts, as demonstrated by (Marí-Dell'Olmo et al. 2021). Population-based studies found similar results where heterogeneity in incidence and

mortality rates (Choe et al. 2021; Mena et al. 2021; Riou et al. 2021) were associated with socioeconomic status showing the importance of planning sanitary policies oriented to the territorial characteristics and specific inequities (Im Kampe et al. 2020; Julieta Politi et al. 2021). It is known that the burden of COVID-19 has affected different socioeconomic groups with different intensity, as observed in this populational study about mortality associated with socioeconomic status in Barcelona, Spain (Julieta Politi et al. 2021).

Knowledge and perception of the risk about COVID-19 was positively associated with infection, which may indicate either, knowledge acquired due to a previous infection, or the large amount of lay knowledge consumed by the young and indeed the general population (Ismail et al. 2021; Hatami et al. 2021). In the same way, a high level of risk perception indicate they understood the risks they had taken.

SARS-CoV-2 Vaccine acceptability

Social determinants and characteristics related to less access to health policies and information had a greater impact on vaccine acceptability, a result also observed in different studies on coverage and acceptability among low-, middle- and high-income countries (Yamey et al. 2022; Solís Arce et al. 2021). Access to adequate health information seems to be an important predictor to vaccine acceptability (Islam et al. 2021; Adane, Ademas, and Kloos 2022; Wong et al. 2021).

In fact, students with higher knowledge about COVID-19 were more likely to accept the vaccine. Students that did not perceive the risk to be infected a SARS-COV-2 infection, were more likely to refuse the vaccine against COVID-19. The confidence in public health authorities can influence the decision to vaccinate or vaccinate persons in their care, and these messages reinforcing vaccine safety and efficacy, when disseminated by health professionals can be useful to minimize vaccine hesitancy and refusal (Viswanath et al. 2021; ECDC 2021; Solís Arce et al. 2021; Pacella-LaBarbara et al. 2021).

The higher transmissibility and increasing infections, in fully vaccinated people included, could be associated with untrust and doubts about the vaccine effectiveness increasing the hesitation. Moreover, unlike the beginning of the pandemic, the perception of risk has changed, and people believe that COVID-19 has become a mild disease now.

Socioeconomic characteristics as obstacles to vaccination strategies, have already been widely described and discussed by the public health community (Viswanath et al. 2021; Nguyen et al. 2021). Our study corroborated these findings. A greater density household or a decrease in the economic situation, parents' migratory situation, when at least one was born abroad but lives in Spain, that was associated with a lower probability to vaccinate their children, or associated with vaccine hesitancy, a similar result was found in a Canadian study (Nazeem Muhajarine et al. 2021), and in this study that demonstrated disparities in vaccination rates among students of different ethnicities (Gurley et al. 2021).

Interestingly, alternative medicines such as homeopathy, that had a negative association with vaccine acceptability among both, parents and adolescents. This can be related to the lower use of health services and distrust of pharmacological therapies by these users. In addition, personal beliefs were already associated with vaccine refusal among parents in previous studies (McKee and Bohannon 2016). A Spanish study found a lower demand for influenza vaccination among homeopathy users, that rejects the vaccine for themselves and for their children (Pinilla and Rodriguez-Caro 2019).

The impact of the COVID-19 on the psychological adolescent's well-being

This study also investigated aspects related to mental health, demonstrating the negative impact of the COVID-19 pandemic on the psychological well-being of adolescents, and how much more severe this impact was on girls. All adolescents experienced more intense emotions than usual linked to the pandemic such as: worry, boredom, frustration, and disappointment, with girls presenting higher mean scores on most of the emotions that negatively affected psychological well-being.

Emerging evidence indicates that girls perceive the impact of COVID-19 on their psychological well-being differently from boys (Pigaiani et al. 2020). The higher percentage of girls than boys that perceived a worsening of mental health due to the pandemic and the higher level of stress caused by general uncertainty it produced is consistent with other studies (Orgilés et al. 2020; Wolf and Schmitz 2023; Saule et al. 2022; Kauhanen et al. 2023; Theberath et al. 2022; Amorós-Reche et al. 2022).

Adolescents often use coping strategies as the use of social media reduce social isolation to deal with the pandemic. In this study, we found gender differences in the use of these

strategies, as the higher proportion of girls doing social activities related to family and/or friends in comparison to boys. This study also shows an association between coping strategies based in unhealthy habits like smoking, and consumption of alcohol and/or drugs and a worsening mental health among both girls and boys, the same result was presented by (Pascoe et al. 2020). Positive coping strategies related to self-care strategies like exercise, were associated with less adverse mental health among girls which has shown mental health benefits for the young as demonstrated by (Tang et al. 2021). Compared to boys, more girls in our sample reported use of tobacco to cope with the pandemic.

The coping strategy related to help from health professionals was reported by few adolescents, most of them girls. Other studies have concluded that young people talk more often about their feelings with family and friends than with professionals, this is partly related to the stigma and embarrassment in seeking mental health services, the negative perceptions of this search and also the lack of knowledge about mental health. (Grove, Marinucci, and Montagni 2023)

Complementary strategies to respiratory disease surveillance among students

Considering the low prevalence of SARS-CoV-2 infections among our study population, (we must test 1,258 participants to find one positive) we designed a pilot study to implement a strategy of syndromic surveillance as complementary tool for predict COVID-19 and others respiratory illness, where we collected information about symptoms and school absence and analyze the association between both and presenting clusters of symptoms among the students.

We found significantly and positively association between school absences and common cold syndrome, demonstrating that symptoms can be a good predictor to events related to school absence, showing that is possible to implement specific forecast models based on real-time data surveillance for the school age population.

Our study reinforces that a strategy based on an active sentinel surveillance seems to be more effective in scenarios with susceptible/sentinel groups, and, therefore, could offer evidence to the public health through analytical models that improve their potential in

providing timely and systematized information about the student's health status, symptoms and their association with school absences, in general.

The approach of the sentinel surveillance could bring more sensibility to detecting a wider range of events and situations being useful to adapt tools and promote better use and allocation of resources and ensure an efficient monitoring model. Moreover, school absences have been already used as a tool for understand the school impact caused by influenza-like events in the schools, moreover other studies also have adapted tools from children's health surveillance, considering that they generally do not communicate their health status very well (Lai et al. 2021; Schmit et al. 2021)

Besides validate a syndromic surveillance pilot among children aged 6-11 years, the early key of this study was scaling the self-application of the survey for students of younger age groups, ensure their participation without increasing the burden of attributions of teachers and health services that have already been largely impacted by the SARS-CoV-2 pandemic.

STUDY LIMITATIONS

Because of the sample of the schools and the participation rate, the study population may not be representative of all schools in Catalonia. Nevertheless, the heterogeneity of the included school's information from different socioeconomical scenarios with a big enough study population. As a sentinel population approach, the objective of the CSSNC is not to extrapolate parameters, but to complement formal epidemiological surveillance systems by means of monitoring them steadily over time population studied. The sample of this study is not representative of the general population, but it is intended to be a source of information associated with the sentinel surveillance system for COVID-19, which are the Sentinel Schools, so it does not need to be representative. The results cannot be generalized to the school population of Catalonia, despite being selected from a representative sample of schools regarding organizational and structural diversity and the epidemiology of the territory.

As a cross-sectional design, association should be interpreted with caution, without attributing causality. Variables such as distal characteristics must be interpreted differently from variables that can change over time such as knowledge, behavior, and contact patterns, which are influenced by the occurrence of the disease. Moreover, the acceptability, compliance, and prevention behaviors, may have been directly affected by the course of the pandemic.

There were some limitations to our longitudinal analysis as the small number of acute infections made impossible to apply a multivariate analysis. Also, with community public health measures occurring simultaneously with the schools' own protocols it was difficult to evaluate these determinants separately. In addition, there was a poor distribution of confounders between groups, which can also have very different sizes, resulting in a loss of statistical power in a multivariate model.

Although the study design was adequate for the purpose of the studying vaccine hesitance, the results should be extrapolated with caution. Predictive capacity of the statistical models applied in this study are considerable high, but, despite the high prevalence of COVID-19 vaccine acceptability in our sample, the study population does not represent the overall children and parents of the country. The sample heterogeneity allows to generate several hypotheses, these would eventually need to be confirmed with population-based surveys. The reported vaccine acceptability may not reflect actual vaccination behavior as well. The fact that vaccination intentions were only asked for those who were not yet vaccinated, have also reduced this population size over time.

This study also presents evidence on the negative impact of the COVID-19 pandemic on emotional wellbeing in adolescents in secondary schools in Catalonia, especially in girls. Adolescents experienced much stronger negative emotions than usual such as worry, irritability, frustration and boredom; with girls presenting a higher proportion of them. More focus must be put on emotions generating emotional discomfort, especially if they are very intense and prolonged, because the absence of adequate tools to manage them can put those who experience them at risk. Therefore, it is important to keep monitoring the medium- and long-term impact of COVID-19 on adolescents and obtain evidence-based information to improve the strategies to promote mental health in schools. Due to the differences between the effects on boys and girls all monitoring must include a gender perspective. Therefore, new research, especially longitudinal studies at different intervals, will be needed to investigate and evaluate this behavior in different periods of COVID-19 vaccination strategies.

Among the limitations of study, no access to pre-pandemic data to confirm a real trend in the indicators among the study population. Several questionnaires used in this study were created specifically to measure impact and characteristics related to the pandemic.

Despite these limitations, it is important to remark that if the study were repeated in the future using serial transversal studies, we could describe the evolution of the impact of the pandemic and the determining factors in post-pandemic periods.

CONCLUSIONS

This study offers a perspective on the occurrence of SARS-CoV-2 infection, knowledge, attitudes and behavior, public health measures compliance, vaccine hesitation, impacts of COVID-19 in the wellbeing of students in Catalonia, Spain, since the COVID-19 pandemic was established as a global concern. The main conclusions of these studies are:

- Highlight the necessity to improvement of the strategies to monitoring closely the health status, risk factors and social determinants in populations at risk.
- The integration of sentinel school surveillance models and routine surveillance can achieve a better understand the impact of determinants and to detect the occurrence of events with greater sensitivity.
- The CSSNC demonstrated, for the first time in Spain, the feasibility of correlating individual socio-epidemiological data and data on the prevalence and incidence of SARS-CoV-2 in the school environment, demonstrating that the public health measures adopted by schools were effective in containing transmission in educational settings.
- Monitoring of biological markers and their behavioral and structural determinants over time in sentinel schools is crucial to assess the health situation and provide relevant information to inform guidelines and policies to increase safety.
- Quality data collected mainly from specific populations combined with sentinel surveillance systems can be a good predictor of the behavior of SARS-CoV-2 or others respiratory viruses and even other infectious diseases, especially in more vulnerable population clusters.
- Understanding determinants and risk factors, makes it possible to build better epidemiological parameters that can allow implementation of epidemiological models to simulate scenarios helping with timely intervention in the face of different emergencies.
- Precaution regarding parental vaccination of children is consistently present across different periods of the pandemic, suggesting that individual risk-benefit continues to guide decision-making processes regarding vaccination.
- Findings on the impact of social and structural factors on COVID-19 vaccine acceptability highlight the importance of specifically targeted interventions to address frequent misunderstandings and reinforce the common benefit of vaccination at the population level.

- The evolving nature of SARS-CoV-2 and the potential role of vaccines in the pediatric population are still full of uncertainties. Both understanding the biological evolution of the virus and the persistence of natural and acquired immune protection will be crucial in defining vaccine recommendations for children.
- With the declaration of the end of the Public Health Emergency of International Concern (PHEIC) by COVID-19, on May 5, 2023 (WHO 2023), the CSSNC project needs to articulate other work areas such as monitoring the occurrence of respiratory viruses, mental health, sexual and reproductive health and substance use patterns as alcohol and other drugs.
- Finally, the emergency response to SARS-CoV-2 needs to leave us a legacy of a health system prepared for increasingly efficient responses to future threats to public health. In this context, strategies based on sentinel surveillance are important to better understand the interaction between different multilevel determinants over time to correctly addresses future interventions.

RECOMENDATIONS

Regarding the occurrence of SARS-CoV-2 and other respiratory viruses among students in Catalonia, their determinants and the association with school absences:

- To monitor through the school-based sentinel surveillance model, the occurrence of SARS-CoV-2 and other respiratory viruses, as well new outcomes detected in among this population.
- To investigate their risk factors and providing information that allows better interventions assessing the impact at the individual level (attitudes, behaviors) as well as at the community level (socioeconomic characteristics).
- Reinforce the surveillance of health events with models and strategies that allow the collection of complementary information to draw better situational diagnoses of the school-age population.
- Implement complementary strategies to obtain timeless data, such as syndromic and environmental surveillance in a school environment.

Regarding students' conducts towards health prevention

- Offer educational centers resources for planning and decision-making, with the involvement of the educational community, researchers, health care workers and other actors.
- Offer information that potentially improves school environment and health promotion regarding topics discussed with the school community.

Regarding COVID-19 vaccine hesitancy.

- Improve access to information about vaccines, overall, aimed at the educational community and adapted to different context, considering both, new scientific evidence and advice.

Regarding the impact in students' psychological wellbeing by COVID-19 pandemic.

- To monitor and evaluate student's mental health to build evidence to improve public mental health policies in partnership with Departments of Health and Education.
- To incorporate gender perspective in the interventions focused on improving the emotional well-being of the educational community.

REFERENCES

- Adane, Metadel, Ayechew Ademas, and Helmut Kloos. 2022. "Knowledge, Attitudes, and Perceptions of COVID-19 Vaccine and Refusal to Receive COVID-19 Vaccine among Healthcare Workers in Northeastern Ethiopia." *BMC Public Health* 22 (1): 128. <https://doi.org/10.1186/s12889-021-12362-8>.
- Ainslie, Kylie E C, Jantien A Backer, Pieter T De Boer, Albert Jan Van Hoek, Don Klinkenberg, Hester Korthals Altes, Ka Yin Leung, Hester De Melker, Fuminari Miura, and Jacco Wallinga. 2022. "A Scenario Modelling Analysis to Anticipate the Impact of COVID-19 Vaccination in Adolescents and Children on Disease Outcomes in the Netherlands, Summer 2021." *Eurosurveillance* 27 (44). <https://doi.org/10.2807/1560-7917.ES.2022.27.44.2101090>.
- Amorós-Reche, Víctor, Ángela Belzunegui-Pastor, Gaspar Hurtado, and Jose P. Espada. 2022. "Emotional Problems in Spanish Children and Adolescents during the COVID-19 Pandemic: A Systematic Review." *Clínica y Salud* 33 (1): 19–28. <https://doi.org/10.5093/clysa2022a2>.
- Balluerka-Lasa, N, J Gómez-Benito, and MD Hidalgo-Montesinos. 2020. "Las Consecuencias Psicológicas de La Covid-19 y El Confinamiento." Servicio de Publicaciones de la Universidad del País Vasco.
- Bastos, Leonardo S, Theodoros Economou, Marcelo F C Gomes, Daniel A M Villela, Flavio C Coelho, Oswaldo G Cruz, Oliver Stoner, Trevor Bailey, and Claudia T Codeço. 2019. "A Modelling Approach for Correcting Reporting Delays in Disease Surveillance Data." *Statistics in Medicine* 38 (22): 4363–77. <https://doi.org/10.1002/sim.8303>.
- Bellei, Nancy, and Thaís Boim Melchior. 2011. "H1N1: Pandemia e Perspectiva Atual." *Jornal Brasileiro de Patologia e Medicina Laboratorial* 47 (6): 611–17. <https://doi.org/10.1590/S1676-24442011000600007>.
- Bi, Qifang, Yongsheng Wu, Shujiang Mei, Chenfei Ye, Xuan Zou, Zhen Zhang, Xiaojian Liu, et al. 2020. "Epidemiology and Transmission of COVID-19 in 391 Cases and 1286 of Their Close Contacts in Shenzhen, China: A Retrospective Cohort Study." *The Lancet Infectious Diseases* 20 (8): 911–19. [https://doi.org/10.1016/S1473-3099\(20\)30287-5](https://doi.org/10.1016/S1473-3099(20)30287-5).
- Bordas, Anna, Antoni Soriano-Arandes, Maria Subirana, Rosina Malagrida, Juliana Maria Reyes-Urueña, Cinta Folch, Pere Soler-Palacin, et al. 2022. "Study Protocol for Monitoring SARS-CoV-2 Infection and Its Determinants in Catalonia (Spain): An Observational and Participatory Research Approach in a Sentinel Network of Schools." *BMJ Open* 12 (1): e055649. <https://doi.org/10.1136/bmjopen-2021-055649>.
- Bubar, Kate M, Kyle Reinholt, Stephen M Kissler, Marc Lipsitch, Sarah Cobey, Yonatan H Grad, and Daniel B Larremore. 2021. "Model-Informed COVID-19 Vaccine Prioritization Strategies by Age and Serostatus."
- Byrne, Alexandra, Lindsay A. Thompson, Stephanie L. Filipp, and Kathleen Ryan. 2022. "COVID-19 Vaccine Perceptions and Hesitancy amongst Parents of School-Aged Children during the Pediatric Vaccine Rollout." *Vaccine* 40 (46): 6680–87. <https://doi.org/10.1016/j.vaccine.2022.09.090>.
- Ceannt, Ruth, Frederique Vallieres, Heather Burns, Jamie Murphy, and Philip Hyland. 2022. "Covid-19 Vaccine Hesitancy and Resistance amongst Parents of Children under 18 Years of Age in Ireland." *Vaccine* 40 (43): 6196–6200. <https://doi.org/10.1016/j.vaccine.2022.08.073>.
- Centre for Disease Prevention, European. 2021. "COVID-19 Surveillance Guidance."
- Choe, Young June, Young-Joon Park, Eun-Young Kim, Myoungyoun Jo, Eun Young Cho, Hyunju Lee, Yun-Kyung Kim, Yae-Jean Kim, and Eun Hwa Choi. 2021.

- “SARS-CoV-2 Transmission in Schools in Korea: Nationwide Cohort Study.” *Arch Dis Child* 0: 1–5. <https://doi.org/10.1136/archdischild-2021-322355>.
- Chowell, Gerardo, Fatima Abdirizak, Sunmi Lee, Jonggul Lee, Eunok Jung, Hiroshi Nishiura, and Cécile Viboud. 2015. “Transmission Characteristics of MERS and SARS in the Healthcare Setting: A Comparative Study.” *BMC Medicine* 13 (1): 210. <https://doi.org/10.1186/s12916-015-0450-0>.
- Clark, Jenna L., Sara B. Algoe, and Melanie C. Green. 2018. “Social Network Sites and Well-Being: The Role of Social Connection.” *Current Directions in Psychological Science* 27 (1): 32–37. <https://doi.org/10.1177/0963721417730833>.
- Cowling, B J, M Park, V J Fang, P Wu, G M Leung, and J T Wu. 2015. “Preliminary Epidemiological Assessment of MERS-CoV Outbreak in South Korea, May to June 2015.” *Eurosurveillance* 20 (25). <https://doi.org/10.2807/1560-7917.ES2015.20.25.21163>.
- Crawshaw, Alison F., Yasmin Farah, Anna Deal, Kieran Rustage, Sally E. Hayward, Jessica Carter, Felicity Knights, et al. 2022. “Defining the Determinants of Vaccine Uptake and Undervaccination in Migrant Populations in Europe to Improve Routine and COVID-19 Vaccine Uptake: A Systematic Review.” *The Lancet. Infectious Diseases* 22 (9): e254–66. [https://doi.org/10.1016/S1473-3099\(22\)00066-4](https://doi.org/10.1016/S1473-3099(22)00066-4).
- Cupertino, Vita, Elena Bozzola, Giampaolo De Luca, Emanuela Del Giudice, Giuseppe De Martino, Piero Cannataro, Alberto Eugenio Tozzi, and Giovanni Corsello. 2022. “The Awareness and Acceptance of Anti-COVID 19 Vaccination in Adolescence.” *Italian Journal of Pediatrics* 48 (1): 194. <https://doi.org/10.1186/s13052-022-01390-8>.
- Dao, Thi Loi, Hue Vu Thi, Philippe Gautret, Jaffar A. Al-Tawfiq, Thanh Lam Nguyen, Dinh Toi Chu, and Van Thuan Hoang. 2023. “Willingness and Attitudes of Parents towards COVID-19 Vaccines for Children in Vietnam.” *Journal of Communication in Healthcare* 16 (1): 75–82. <https://doi.org/10.1080/17538068.2022.2150207>.
- Dembek, Z. F., T. Chekol, and A. Wu. 2018. “Best Practice Assessment of Disease Modelling for Infectious Disease Outbreaks.” *Epidemiology and Infection* 146 (10): 1207–15. <https://doi.org/10.1017/S095026881800119X>.
- Diaz-Quijano, Fredi A., José M.N. da Silva, Fabiana Ganem, Silvano Oliveira, Andrea L. Vesga-Varela, and Julio Croda. 2020. “A Model to Predict SARS-CoV-2 Infection Based on the First Three-Month Surveillance Data in Brazil.” *Tropical Medicine and International Health* 25 (11): 1385–94. <https://doi.org/10.1111/tmi.13476>.
- Dong, Ensheng, Hongru Du, and Lauren Gardner. 2020. “An Interactive Web-Based Dashboard to Track COVID-19 in Real Time.” *The Lancet Infectious Diseases* 20 (5): 533–34. [https://doi.org/10.1016/S1473-3099\(20\)30120-1](https://doi.org/10.1016/S1473-3099(20)30120-1).
- Dr. M. Dhanabhakyaam and Sarath M. 2023. “Psychological Wellbeing: Asystematic Literature Review.” *International Journal of Advanced Research in Science, Communication and Technology*, February, 603–7. <https://doi.org/10.48175/IJARSCT-8345>.
- Drosten, Christian, Stephan Günther, Wolfgang Preiser, Sylvie Van Der Werf, Hans-Reinhard Brodt, Stephan Becker, Holger Rabenau, et al. 2003. “Identification of a Novel Coronavirus in Patients with Severe Acute Respiratory Syndrome.” *New England Journal of Medicine* 348 (20): 1967–76. <https://doi.org/10.1056/NEJMoa030747>.

- Du, Yuxuan, Long Chen, and Yuan Shi. 2022. "Safety, Immunogenicity, and Efficacy of COVID-19 Vaccines in Adolescents, Children, and Infants: A Systematic Review and Meta-Analysis." *Frontiers in Public Health* 10: 829176. <https://doi.org/10.3389/fpubh.2022.829176>.
- Dubé, Eve, Dominique Gagnon, and Catherine Pelletier. 2022. "COVID-19 Vaccination in 5-11 Years Old Children: Drivers of Vaccine Hesitancy among Parents in Quebec." *Human Vaccines & Immunotherapeutics* 18 (1): 2028516. <https://doi.org/10.1080/21645515.2022.2028516>.
- Dvorsky, Melissa R., Rosanna Breaux, Caroline N. Cusick, Joseph W. Fredrick, Cathrin Green, Amanda Steinberg, Joshua M. Langberg, Emma Sciberras, and Stephen P. Becker. 2022. "Coping with COVID-19: Longitudinal Impact of the Pandemic on Adjustment and Links with Coping for Adolescents with and without ADHD." *Research on Child and Adolescent Psychopathology* 50 (5): 605–19. <https://doi.org/10.1007/s10802-021-00857-2>.
- ECDC. 2021. "Interim Public Health Considerations for COVID-19 Vaccination of Adolescents in the EU/EEA."
- Enria, Delia, Zijian Feng, Atle Fretheim, Chikwe Ihekweazu, Trygve Ottersen, Anne Schuchat, Kumnuan Ungchusak, et al. 2021. "Strengthening the Evidence Base for Decisions on Public Health and Social Measures." *Bulletin of the World Health Organization* 99 (09): 610-610A. <https://doi.org/10.2471/BLT.21.287054>.
- Ertem, Zeynep, Elissa M Schechter-Perkins, Emily Oster, Polly Berg, Isabella Epshtein, Nathorn Chaiyakunapruk, Fernando A Wilson, et al. 2021. "The Impact of School Opening Model on SARS-CoV-2 Community Incidence and Mortality." *Nature Medicine* 27: 2120–26. <https://doi.org/10.1038/s41591-021-01563-8>.
- Escosa-García, Luis, David Aguilera-Alonso, Cristina Calvo, María José Mellado, and Fernando Baquero-Artigao. 2020. "Ten Key Points about COVID-19 in Children: The Shadows on the Wall." *Pediatric Pulmonology* 55 (10): 2576–86. <https://doi.org/10.1002/ppul.25025>.
- España, Ministerio de Sanidad, and Grupo de trabajo técnico de vacunación COVID-19. 2021. "Estrategia de Vacunación Frente a COVID19 En España - Actualización 2." <https://www.sanidad.gob.es/profesionales/saludPublica/ccayes/alertasActual/nCov/vacunaCovid19.htm>.
- España, MP. 2020. "Real Decreto 463/2020, de 14 de Marzo, Por El Que Se Declara El Estado de Alarma Para La Gestión de La Situación de Crisis Sanitaria Ocasionada Por El COVID-19." Boletín Oficial del Estado 67. España: MINISTERIO DE LA PRESIDENCIA, RELACIONES CON LAS CORTES Y MEMORIA DEMOCRÁTICA. <https://www.boe.es/boe/dias/2020/03/14/pdfs/BOE-A-2020-3692.pdf>.
- Esposito, Susanna, Nicola Cotugno, and Nicola Principi. 2021. "Comprehensive and Safe School Strategy during COVID-19 Pandemic." *Italian Journal of Pediatrics* 47 (1): 6. <https://doi.org/10.1186/s13052-021-00960-6>.
- Folch, Cinta, Helena González-Casals, Joan Colom, Marina Bosque-Prous, Tivy Barón-García, Anaís Álvarez-Vargas, Jordi Casabona, and Albert Espelt. 2022. "Mental Well-Being during the COVID-19 Confinement among Adolescents in Catalonia: The Role of Demographic and Other COVID-Related Variables." *Children* 9 (6): 783. <https://doi.org/10.3390/children9060783>.
- Folkman, Susan, and Richard S. Lazarus. 1980. "An Analysis of Coping in a Middle-Aged Community Sample." *Journal of Health and Social Behavior* 21 (3): 219. <https://doi.org/10.2307/2136617>.

- Fox, Helen C., and Rajita Sinha. 2009. "Sex Differences in Drug-Related Stress-System Changes: Implications for Treatment in Substance-Abusing Women." *Harvard Review of Psychiatry* 17 (2): 103–19. <https://doi.org/10.1080/10673220902899680>.
- Foy, Brody H., Brian Wahl, Kayur Mehta, Anita Shet, Gautam I. Menon, and Carl Britto. 2021. "Comparing COVID-19 Vaccine Allocation Strategies in India: A Mathematical Modelling Study." *International Journal of Infectious Diseases* 103 (February): 431–38. <https://doi.org/10.1016/j.ijid.2020.12.075>.
- Gallo, Luciana Guerra, Ana Flávia de Moraes Oliveira, Amanda Amaral Abrahão, Leticia Assad Maia Sandoval, Yure Rodrigues Araújo Martins, Maria Almirón, Fabiana Sherine Ganem dos Santos, Wildo Navegantes Araújo, Maria Regina Fernandes de Oliveira, and Henry Maia Peixoto. 2020. "Ten Epidemiological Parameters of COVID-19: Use of Rapid Literature Review to Inform Predictive Models During the Pandemic." *Frontiers in Public Health* 8 (December). <https://doi.org/10.3389/fpubh.2020.598547>.
- Ganem, Fabiana, Lucia Alonso, Andreu Colom-Cadena, Anna Bordas, Cinta Folch, Antoni Soriano-Arandes, and Jordi Casabona. 2023. "Syndromic Surveillance as a Predictive Tool for Health-Related School Absences in COVID-19 Sentinel Schools in Catalonia, Spain." Preprint. *Epidemiology*. <https://doi.org/10.1101/2023.03.24.23287681>.
- Ganem, Fabiana, Anna Bordas, Cinta Folch, Lucia Alonso, Marcos Montoro-Fernandez, Andreu Colom-Cadena, Ariadna Mas, et al. 2022. "The COVID-19 Sentinel Schools Network of Catalonia (CSSNC) Project: Associated Factors to Prevalence and Incidence of SARS-CoV-2 Infection in Educational Settings during the 2020–2021 Academic Year." *PLOS ONE* 17 (11): e0277764. <https://doi.org/10.1371/journal.pone.0277764>.
- Ganem, Fabiana, Cinta Folch, Andreu Colom-Cadena, Anna Bordas, Lucia Alonso, Antoni Soriano-Arandes, Jordi Casabona, and on behalf of Sentinel School Network Study Group of Catalonia. 2023. "Determinants of COVID-19 Vaccine Hesitancy among Students and Parents in Sentinel Schools Network of Catalonia, Spain." Edited by Harapan Harapan. *PLOS ONE* 18 (3): e0282871. <https://doi.org/10.1371/journal.pone.0282871>.
- Generalitat de Catalunya. 2022a. "Covid-19: Informació Estadística per al Seguiment de l'impacte de La Pandèmia." Institut d'Estadística de Catalunya. <https://www.idescat.cat/>.
- . 2022b. "Dades Obertes i COVID-19." https://governobert.gencat.cat/es/dades_obertes/dades-obertes-covid-19/.
- Generalitat de Catalunya. Departament de Salut. 2020. "Procediment d'actuació Enfront de Casos d'infecció Pel Nou Coronavirus SARS-CoV-2." https://canalsalut.gencat.cat/web/.content/_A-Z/C/coronavirus-2019-ncov/material-
- Generalitat de Catalunya. Departament d'Educació. 2020. "Gestió de Casos de COVID-19 Als Centres Educatius."
- Goldstein, Edward, Marc Lipsitch, and Muge Cevik. 2021. "On the Effect of Age on the Transmission of SARS-CoV-2 in Households, Schools, and the Community." *Journal of Infectious Diseases* 223 (3): 362–69. <https://doi.org/10.1093/infdis/jiaa691>.
- Golemis, Adrianos, Panteleimon Voitsidis, Eleni Parlapani, Vasiliki A Nikopoulou, Virginia Tsipropoulou, Panayiota Karamouzi, Aikaterini Giatzkoulidou, et al. 2022. "Young Adults' Coping Strategies against Loneliness during the COVID-

- 19-Related Quarantine in Greece.” *Health Promotion International* 37 (1): daab053. <https://doi.org/10.1093/heapro/daab053>.
- Grove, Christine, Alexandra Marinucci, and Ilaria Montagni. 2023. “Australian Youth Resilience and Help-Seeking during COVID-19: A Cross-Sectional Study.” *Behavioral Sciences* 13 (2): 121. <https://doi.org/10.3390/bs13020121>.
- Gurley, Stephen, Brady Bennett, Patrick Sullivan, Maryellen Kiley, Jamie Linde, David Szczerbacki, and Jodie Guest. 2021. “COVID-19 Vaccine Perceptions, Intentions, and Uptake: A Prospective College-Based Cohort Study (Preprint).” *JMIR Public Health and Surveillance*, December. <https://doi.org/10.2196/33739>.
- Halldorsdottir, Thorhildur, Ingibjorg Eva Thorisdottir, Caine C. A. Meyers, Bryndis Bjork Asgeirsdottir, Alfgeir Logi Kristjansson, Heiddis B. Valdimarsdottir, John P. Allegrante, and Inga Dora Sigfusdottir. 2021. “Adolescent Well-being amid the COVID-19 Pandemic: Are Girls Struggling More than Boys?” *JCPP Advances* 1 (2): e12027. <https://doi.org/10.1002/jcv2.12027>.
- Harris, Ross J., Jennifer A. Hall, Asad Zaidi, Nick J. Andrews, J. Kevin Dunbar, and Gavin Dabrera. 2021. “Effect of Vaccination on Household Transmission of SARS-CoV-2 in England.” *New England Journal of Medicine* 385 (8): 759–60. <https://doi.org/10.1056/NEJMc2107717>.
- Hassan, Sehar-un-Nisa, Fahad D. Algahtani, Mohammad Raafat Atteya, Ali A. Almishaal, Ahmed A. Ahmed, Sofian T. Obeidat, Reham Mohamed Kamel, and Rania Fathy Mohamed. 2021. “The Impact of Extended E-Learning on Emotional Well-Being of Students during the COVID-19 Pandemic in Saudi Arabia.” *Children* 9 (1): 13. <https://doi.org/10.3390/children9010013>.
- Hatami, Hossein, Mohsen Abbasi-Kangevari, Mohammad-Reza Malekpour, and Ali-Asghar Kolahi. 2021. “Knowledge, Attitudes, and Safety Practices About COVID-19 Among High School Students in Iran During the First Wave of the Pandemic.” *Frontiers in Public Health* 9 (August). <https://doi.org/10.3389/fpubh.2021.680514>.
- Hellewell, Joel, Sam Abbott, Amy Gimma, Nikos I Bosse, Christopher I Jarvis, Timothy W Russell, James D Munday, et al. 2020. “Feasibility of Controlling COVID-19 Outbreaks by Isolation of Cases and Contacts.” *The Lancet Global Health* 8 (4): e488–96. [https://doi.org/10.1016/S2214-109X\(20\)30074-7](https://doi.org/10.1016/S2214-109X(20)30074-7).
- Hoyt, Lindsay Till, Miranda P. Dotson, Ahna Ballonoff Suleiman, Natasha L. Burke, Jasmine B. Johnson, and Alison K. Cohen. 2023. “Internalizing the COVID-19 Pandemic: Gendered Differences in Youth Mental Health.” *Current Opinion in Psychology* 52 (August): 101636. <https://doi.org/10.1016/j.copsy.2023.101636>.
- Ibrahim, Nahla Khamis. 2020. “Epidemiologic Surveillance for Controlling Covid-19 Pandemic: Types, Challenges and Implications.” *Journal of Infection and Public Health* 13 (11): 1630–38. <https://doi.org/10.1016/j.jiph.2020.07.019>.
- Im Kampe, Eveline Otte, Ann Sophie Lehfeld, Silke Buda, Udo Buchholz, and Walter Haas. 2020. “Surveillance of COVID-19 School Outbreaks, Germany, March to August 2020.” *Eurosurveillance* 25 (38). <https://doi.org/10.2807/1560-7917.ES.2020.25.38.2001645>.
- Ingelbeen, Brecht, Laurène Peckeu, Marie Laga, Ilona Hendrix, Inge Neven, Marianne A.B. van der Sande, and Esther van Kleef. 2021. “Reducing Contacts to Stop SARS-CoV-2 Transmission during the Second Pandemic Wave in Brussels, Belgium, August to November 2020.” *Eurosurveillance* 26 (7). <https://doi.org/10.2807/1560-7917.ES.2021.26.7.2100065>.
- Islam, Md. Saiful, Abu Bakkar Siddique, Rejina Akter, Rafia Tasnim, Md. Safaet Hossain Sujon, Paul R. Ward, and Md. Tajuddin Sikder. 2021. “Knowledge, Attitudes and

- Perceptions towards COVID-19 Vaccinations: A Cross-Sectional Community Survey in Bangladesh.” *BMC Public Health* 21 (1): 1851. <https://doi.org/10.1186/s12889-021-11880-9>.
- Ismail, Sharif A, Vanessa Saliba, Jamie Lopez Bernal, Mary E Ramsay, and Shamez N Ladhani. 2021. “SARS-CoV-2 Infection and Transmission in Educational Settings: A Prospective, Cross-Sectional Analysis of Infection Clusters and Outbreaks in England.” *The Lancet Infectious Diseases* 21 (3): 344–53. [https://doi.org/10.1016/S1473-3099\(20\)30882-3](https://doi.org/10.1016/S1473-3099(20)30882-3).
- Jeong, Darae, Chang Hyeong Lee, Yongho Choi, and Junseok Kim. 2016. “The Daily Computed Weighted Averaging Basic Reproduction Number R_0 , k , ω n for MERS-CoV in South Korea.” *Physica A: Statistical Mechanics and Its Applications* 451 (June): 190–97. <https://doi.org/10.1016/j.physa.2016.01.072>.
- Jorge, D C P, J F Oliveira, J G V Miranda, R F S Andrade, and S T R Pinho. 2022. “Estimating the Effective Reproduction Number for Heterogeneous Models Using Incidence Data.” <https://doi.org/10.1098/rsos.220005>.
- Julieta Politi, Mario Martín-Sánchez, Lilas Mercuriali, Blanca Borrás-Bermejo, Joaquín Lopez-Contreras, Anna Vilella, Judit Villar, et al. 2021. “Epidemiological Characteristics and Outcomes of COVID-19 Cases: Mortality Inequalities by Socioeconomic Status, Barcelona, Spain, 24 February to 4 May 2020.” *Eurosurveillance* 26 (20). <https://doi.org/10.2807/1560-7917>.
- Kang, Sifan, Yuliang Sun, Xinxin Zhang, Fangjun Sun, Bingqi Wang, and Wenfei Zhu. 2020. “Is Physical Activity Associated with Mental Health among Chinese Adolescents during Isolation in COVID-19 Pandemic?:” *Journal of Epidemiology and Global Health* 11 (1): 26. <https://doi.org/10.2991/jegh.k.200908.001>.
- Kauhanen, Laura, Wan Mohd Azam Wan Mohd Yunus, Lotta Lempinen, Kirsi Peltonen, David Gyllenberg, Kaisa Mishina, Sonja Gilbert, Kalpana Bastola, June S. L. Brown, and Andre Sourander. 2023. “A Systematic Review of the Mental Health Changes of Children and Young People before and during the COVID-19 Pandemic.” *European Child & Adolescent Psychiatry* 32 (6): 995–1013. <https://doi.org/10.1007/s00787-022-02060-0>.
- Keeling, Matt J., Michael J. Tildesley, Benjamin D. Atkins, Bridget Penman, Emma Southall, Glen Guyver-Fletcher, Alex Holmes, et al. 2021. “The Impact of School Reopening on the Spread of COVID-19 in England.” *Philosophical Transactions of the Royal Society B: Biological Sciences* 376 (1829). <https://doi.org/10.1098/rstb.2020.0261>.
- Kilbourne, Edwin D. 2006. “Influenza Pandemics of the 20th Century.” *Emerging Infectious Diseases* 12 (1): 9–14. <https://doi.org/10.3201/eid1201.051254>.
- Kim, Soyoun, Yae-Jean Kim, Kyong Ran Peck, and Eunok Jung. 2020. “School Opening Delay Effect on Transmission Dynamics of Coronavirus Disease 2019 in Korea: Based on Mathematical Modeling and Simulation Study.” *Journal of Korean Medical Science* 35 (13). <https://doi.org/10.3346/jkms.2020.35.e143>.
- Kirsten, Carolin, Manja Unrath, Christian Lück, Alexander H Dalpke, Reinhard Berner, and Jakob Armann. 2021. “SARS-CoV-2 Seroprevalence in Students and Teachers: A Longitudinal Study from May to October 2020 in German Secondary Schools.” *BMJ Open* 11: 49876. <https://doi.org/10.1136/bmjopen-2021-049876>.
- Knight, Julia A, Rebecca D Kehm, Lisa Schwartz, Caren J Frost, Wendy K Chung, Sarah Colonna, Theresa H M Keegan, et al. 2021. “Prepubertal Internalizing Symptoms and Timing of Puberty Onset in Girls.” *American Journal of Epidemiology* 190 (3): 431–38. <https://doi.org/10.1093/aje/kwaa223>.

- Kriemler, Susi, Agne Ulyte, Priska Ammann, Gabriela P. Peralta, Christoph Berger, Milo A. Puhan, and Thomas Radtke. 2021. "Surveillance of Acute SARS-CoV-2 Infections in School Children and Point-Prevalence During a Time of High Community Transmission in Switzerland." *Frontiers in Pediatrics* 9 (March). <https://doi.org/10.3389/fped.2021.645577>.
- Krishnaratne, Shari, Lisa M Pfadenhauer, Michaela Coenen, Karin Geffert, Caroline Jung-Sievers, Carmen Klinger, Suzie Kratzer, et al. 2020. "Measures Implemented in the School Setting to Contain the COVID-19 Pandemic: A Rapid Scoping Review." *Cochrane Database of Systematic Reviews* 2020 (12). <https://doi.org/10.1002/14651858.CD013812>.
- Kyei-Arthur, Frank, Sylvester Kyei-Gyamfi, Martin Wiredu Agyekum, Grace Frempong Afrifa-Anane, and Bernard Akyeampong Amoh. 2022. "Parents' and Guardians' Acceptability of COVID-19 Vaccination for Children in Ghana: An Online Survey." *PloS One* 17 (8): e0272801. <https://doi.org/10.1371/journal.pone.0272801>.
- Lai, Jennifer, Helen E Hughes, Roger Morbey, Paul Loveridge, Jamie Lopez Bernal, Vanessa Saliba, Esther Kissling, Alex Lovelock-Wren, Jeremy Mabbitt, and Alex J Elliot. 2021. "Epidemiology and Infection Developing a Sentinel Syndromic Surveillance System Using School-Absenteeism Data, Example Monitoring Absences over the 2020 COVID-19 Pandemic." *Epidemiology and Infection* 149. <https://doi.org/10.1017/S0950268821002399>.
- Lin, Jessica A., Sara F. Forman, Carly Milliren, Julia Vitagliano, Rebecca Spigel, Elizabeth R. Woods, and Tracy K. Richmond. 2021. "Eating Disorder Recovery: The Relationship Between Malnutrition and Symptoms of Anxiety/Depression in Youth With Restrictive Eating Disorders." *Journal of Adolescent Health* 68 (2): S52–53. <https://doi.org/10.1016/j.jadohealth.2020.12.108>.
- Liu, Y., Q. Ma, H. Liu, and Z. Guo. 2022. "Public Attitudes and Influencing Factors toward COVID-19 Vaccination for Adolescents/Children: A Scoping Review." *Public Health* 205 (April): 169–81. <https://doi.org/10.1016/j.puhe.2022.02.002>.
- Llupià, Anna, Alícia Borràs-Santos, Caterina Guinovart, Mireia Utzet, David Moríña, and Joaquim Puig. 2021. "SARS-CoV-2 Transmission in Students of Public Schools of Catalonia (Spain) after a Month of Reopening." *PLOS ONE* 16 (5): e0251593. <https://doi.org/10.1371/journal.pone.0251593>.
- Lo Moro, Giuseppina, Tiziana Sinigaglia, Fabrizio Bert, Armando Savatteri, Maria Rosaria Gualano, and Roberta Siliquini. 2020. "Reopening Schools during the COVID-19 Pandemic: Overview and Rapid Systematic Review of Guidelines and Recommendations on Preventive Measures and the Management of Cases." *International Journal of Environmental Research and Public Health* 17 (23): 1–21. <https://doi.org/10.3390/ijerph17238839>.
- López-Bueno, Rubén, Guillermo F. López-Sánchez, José A. Casajús, Joaquín Calatayud, Mark A. Tully, and Lee Smith. 2021. "Potential Health-Related Behaviors for Pre-School and School-Aged Children during COVID-19 Lockdown: A Narrative Review." *Preventive Medicine* 143 (February). <https://doi.org/10.1016/j.ypmed.2020.106349>.
- Lugon, amella, Trevon Fuller, Luana Damasceno, Guilherme Calvet, Paola Cristina Resende, Aline Rocha Matos, Tulio Machado Fumian, et al. 2021. "SARS-CoV-2 Infection Dynamics in Children and Household Contacts in a Slum in Rio de Janeiro ARTICLE." *Pediatrics* 148 (1): 2021050182. <https://doi.org/10.1542/peds.2021-050182>.

- Macartney, Kristine, Helen E. Quinn, Alexis J. Pillsbury, Archana Koirala, Lucy Deng, Noni Winkler, Anthea L. Katelaris, et al. 2020. "Transmission of SARS-CoV-2 in Australian Educational Settings: A Prospective Cohort Study." *The Lancet Child and Adolescent Health* 4 (11): 807–16. [https://doi.org/10.1016/S2352-4642\(20\)30251-0](https://doi.org/10.1016/S2352-4642(20)30251-0).
- Magson, Natasha R., Justin Y. A. Freeman, Ronald M. Rapee, Cele E. Richardson, Ella L. Oar, and Jasmine Fardouly. 2021. "Risk and Protective Factors for Prospective Changes in Adolescent Mental Health during the COVID-19 Pandemic." *Journal of Youth and Adolescence* 50 (1): 44–57. <https://doi.org/10.1007/s10964-020-01332-9>.
- Manivannan, Madhumitha, Manasi P Jogalekar, Muthu Subash Kavitha, Balu Alagar Venmathi Maran, and Prakash Gangadaran. 2021. "A Mini-Review on the Effects of COVID-19 on Younger Individuals." *Experimental Biology and Medicine* 246 (3): 293–97. <https://doi.org/10.1177/1535370220975118>.
- Marco-Ahulló, Adrià, Israel Villarrasa-Sapiña, and Gonzalo Monfort-Torres. 2021. "Estudio Descriptivo Sobre Las Diferencias de Género En El Estrés Académico Derivado Del Contexto COVID-19 En Población Universitaria Española (Descriptive Study on Gender Differences in Academic Stress Derived from the COVID-19 Context in a Spanish Unive." *Retos* 43 (September): 845–51. <https://doi.org/10.47197/retos.v43i0.88968>.
- Marí-Dell’Olmo, Marc, Mercè Gotsens, M Isabel Pasarín, Maica Rodríguez-Sanz, Lucía Artazcoz, Patricia Garcia de Olalla, Cristina Rius, and Carme Borrell. 2021. "Socioeconomic Inequalities in COVID-19 in a European Urban Area: Two Waves, Two Patterns." *International Journal of Environmental Research and Public Health* 18 (3): 1256. <https://doi.org/10.3390/ijerph18031256>.
- Marks, Michael, Pere Millat-Martinez, Dan Ouchi, Chrissy h. Roberts, Andrea Alemany, Marc Corbacho-Monné, Maria Ubals, et al. 2021. "Transmission of COVID-19 in 282 Clusters in Catalonia, Spain: A Cohort Study." *The Lancet Infectious Diseases* 21 (5): 629–36. [https://doi.org/10.1016/S1473-3099\(20\)30985-3/ATTACHMENT/59270188-9308-4D12-9A13-4C1F5A58D3BB/MMC2.PDF](https://doi.org/10.1016/S1473-3099(20)30985-3/ATTACHMENT/59270188-9308-4D12-9A13-4C1F5A58D3BB/MMC2.PDF).
- McKee, Chephra, and Kristin Bohannon. 2016. "Exploring the Reasons Behind Parental Refusal of Vaccines." *The Journal of Pediatric Pharmacology and Therapeutics* 21 (2): 104–9. <https://doi.org/10.5863/1551-6776-21.2.104>.
- Mena, Gonzalo E., Pamela P. Martinez, Ayesha S. Mahmud, Pablo A. Marquet, Caroline O. Buckee, and Mauricio Santillana. 2021. "Socioeconomic Status Determines COVID-19 Incidence and Related Mortality in Santiago, Chile." *Science* 372 (6545). <https://doi.org/10.1126/science.abg5298>.
- Molero Jurado, María Del Mar, María Del Carmen Pérez-Fuentes, Elena Fernández-Martínez, África Martos Martínez, and José Jesús Gázquez Linares. 2021. "Coping Strategies in the Spanish Population: The Role in Consequences of COVID-19 on Mental Health." *Frontiers in Psychiatry* 12 (April): 606621. <https://doi.org/10.3389/fpsy.2021.606621>.
- Moore, Sam, Edward M Hill, Michael J Tildesley, Louise Dyson, and Matt J Keeling. 2021. "Vaccination and Non-Pharmaceutical Interventions for COVID-19: A Mathematical Modelling Study." *The Lancet Infectious Diseases* 21 (6): 793–802. [https://doi.org/10.1016/S1473-3099\(21\)00143-2](https://doi.org/10.1016/S1473-3099(21)00143-2).
- Munday, James D., Christopher I. Jarvis, Amy Gimma, Kerry L.M. Wong, Kevin van Zandvoort, Yang Liu, Joel Hellewell, et al. 2021. "Estimating the Impact of Reopening Schools on the Reproduction Number of SARS-CoV-2 in England,

- Using Weekly Contact Survey Data.” *BMC Medicine* 19 (1).
<https://doi.org/10.1186/s12916-021-02107-0>.
- Nazeem Muhajarine, Daniel A Adeyinka, Jessica Mccutcheon, Kathryn L Green, Miles Fahlman Id, and Natalie Kallio Id. 2021. “COVID-19 Vaccine Hesitancy and Refusal and Associated Factors in an Adult Population in Saskatchewan, Canada: Evidence from Predictive Modelling.”
<https://doi.org/10.1371/journal.pone.0259513>.
- Nearchou, Finiki, Clodagh Flinn, Rachel Niland, Sheena Siva Subramaniam, and Eilis Hennessy. 2020. “Exploring the Impact of COVID-19 on Mental Health Outcomes in Children and Adolescents: A Systematic Review.” *International Journal of Environmental Research and Public Health* 17 (22): 8479.
<https://doi.org/10.3390/ijerph17228479>.
- Nguyen, Trung, Mehnaz Adnan, Binh P Nguyen, Joep de Ligt, Jemma L Geoghegan, Richard Dean, Sarah Jefferies, et al. 2021. “COVID-19 Vaccine Strategies for Aotearoa New Zealand: A Mathematical Modelling Study.” *The Lancet Regional Health - Western Pacific* 15 (October): 100256.
<https://doi.org/10.1016/j.lanwpc.2021.100256>.
- Oboho, Ikwo K., Sara M. Tomczyk, Ahmad M. Al-Asmari, Ayman A. Banjar, Hani Al-Mugti, Muhannad S. Aloraini, Khulud Z. Alkhalidi, et al. 2015. “2014 MERS-CoV Outbreak in Jeddah — A Link to Health Care Facilities.” *New England Journal of Medicine* 372 (9): 846–54. <https://doi.org/10.1056/NEJMoa1408636>.
- Olusanya, Olufunto A, Robert A Bednarczyk, Robert L Davis, Arash Shaban-Nejad, Viviana Moschese, Baldassarre Martire, Raffaele Dimiccoli Hospital, Italy Srinivasa, and Reddy Bonam. 2021. “Addressing Parental Vaccine Hesitancy and Other Barriers to Childhood/Adolescent Vaccination Uptake During the Coronavirus (COVID-19) Pandemic.” *Article* 12: 1.
<https://doi.org/10.3389/fimmu.2021.663074>.
- Orgilés, Mireia, Alexandra Morales, Elisa Delvecchio, Claudia Mazzeschi, and José P. Espada. 2020. “Immediate Psychological Effects of the COVID-19 Quarantine in Youth From Italy and Spain.” *Frontiers in Psychology* 11 (November): 579038.
<https://doi.org/10.3389/fpsyg.2020.579038>.
- Pacella-LaBarbara, Maria L., Yunseo Linda Park, P. Daniel Patterson, Ankur Doshi, Maria Koenig Guyette, Ambrose H. Wong, Bernard P. Chang, and Brian P. Suffoletto. 2021. “COVID-19 Vaccine Uptake and Intent Among Emergency Healthcare Workers: A Cross-Sectional Survey.” *Journal of Occupational and Environmental Medicine* 63 (10): 852–56.
<https://doi.org/10.1097/JOM.0000000000002298>.
- Park, Young Joon, Young June Choe, Ok Park, Shin Young Park, Young-Man Kim, Jieun Kim, Sanghui Kweon, et al. 2020. “Contact Tracing during Coronavirus Disease Outbreak, South Korea, 2020.” *Emerging Infectious Diseases* 26 (10): 2465–68.
<https://doi.org/10.3201/eid2610.201315>.
- Pascoe, Michaela, Alan P Bailey, Melinda Craike, Tim Carter, Rhiannon Patten, Nigel Stepto, and Alexandra Parker. 2020. “Physical Activity and Exercise in Youth Mental Health Promotion: A Scoping Review.” *BMJ Open Sport & Exercise Medicine* 6 (1): e000677. <https://doi.org/10.1136/bmjsem-2019-000677>.
- Pei, Sen, Xian Teng, Paul Lewis, and Jeffrey Shaman. 2021. “Optimizing Respiratory Virus Surveillance Networks Using Uncertainty Propagation.” *Nature Communications* 12 (1): 222. <https://doi.org/10.1038/s41467-020-20399-3>.
- Perramon, Aida, Antoni Soriano-Arandes, David Pino, Uxue Lazcano, Cristina Andrés, Martí Català, Anna Gatell, et al. 2021. “Schools as a Framework for COVID-19

- Epidemiological Surveillance of Children in Catalonia, Spain: A Population-Based Study.” *Frontiers in Pediatrics* 9 (September). <https://doi.org/10.3389/fped.2021.754744>.
- Pigaiani, Yolande, Leonardo Zoccante, Anastasia Zocca, Athos Arzenton, Marco Menegolli, Sabrina Fadel, Mirella Ruggeri, and Marco Colizzi. 2020. “Adolescent Lifestyle Behaviors, Coping Strategies and Subjective Wellbeing during the COVID-19 Pandemic: An Online Student Survey.” *Healthcare* 8 (4): 472. <https://doi.org/10.3390/healthcare8040472>.
- Pinilla, Jaime, and Alejandro Rodriguez-Caro. 2019. “Differences in Healthcare Utilisation between Users and Non-Users of Homeopathic Products in Spain: Results from Three Waves of the National Health Survey (2011-2017).” *PLOS ONE* 14 (5): e0216707. <https://doi.org/10.1371/journal.pone.0216707>.
- Pollán, Marina, Beatriz Pérez-Gómez, Roberto Pastor-Barriuso, Jesús Oteo, Miguel A Hernán, Mayte Pérez-Olmeda, Jose L Sanmartín, et al. 2020. “Prevalence of SARS-CoV-2 in Spain (ENE-COVID): A Nationwide, Population-Based Seroepidemiological Study.” *The Lancet* 396 (10250): 535–44. [https://doi.org/10.1016/S0140-6736\(20\)31483-5](https://doi.org/10.1016/S0140-6736(20)31483-5).
- Potter, C.W. 2001. “A History of Influenza.” *Journal of Applied Microbiology* 91 (4): 572–79. <https://doi.org/10.1046/j.1365-2672.2001.01492.x>.
- Qin, Chenyuan, Ruitong Wang, Liyuan Tao, Min Liu, and Jue Liu. 2022. “Association Between Risk Perception and Acceptance for a Booster Dose of COVID-19 Vaccine to Children Among Child Caregivers in China.” *Frontiers in Public Health* 10: 834572. <https://doi.org/10.3389/fpubh.2022.834572>.
- Rees, Franziska, Mattis Geiger, Lau Lilleholt, Ingo Zettler, Cornelia Betsch, Robert Böhm, and Oliver Wilhelm. 2022. “Measuring Parents’ Readiness to Vaccinate Themselves and Their Children against COVID-19.” *Vaccine* 40 (28): 3825–34. <https://doi.org/10.1016/j.vaccine.2022.04.091>.
- Rella, Simon A., Yuliya A. Kulikova, Emmanouil T. Dermitzakis, and Fyodor A. Kondrashov. 2021. “Rates of SARS-CoV-2 Transmission and Vaccination Impact the Fate of Vaccine-Resistant Strains.” *Scientific Reports* 11 (1): 15729. <https://doi.org/10.1038/s41598-021-95025-3>.
- Riazi, Negin A., Katelyn Battista, Markus J. Duncan, Terrance J. Wade, William Pickett, Mark A. Ferro, Scott T. Leatherdale, and Karen A. Patte. 2023. “Stronger Together: Coping Behaviours and Mental Health Changes of Canadian Adolescents in Early Phases of the COVID-19 Pandemic.” *BMC Public Health* 23 (1): 319. <https://doi.org/10.1186/s12889-023-15249-y>.
- Riou, Julien, Radoslaw Panczak, Christian L. Althaus, Christoph Junker, Damir Perisa, Katrin Schneider, Nicola G. Criscuolo, Nicola Low, and Matthias Egger. 2021. “Socioeconomic Position and the COVID-19 Care Cascade from Testing to Mortality in Switzerland: A Population-Based Analysis.” *The Lancet Public Health* 6 (9): e683–91. [https://doi.org/10.1016/S2468-2667\(21\)00160-2](https://doi.org/10.1016/S2468-2667(21)00160-2).
- RNVE. 2023. “Situación de COVID-19 En España. Informe N° 178.” 178. Spain: Red Nacional de Vigilancia Epidemiológica.
- Rogés, Judit, Marina Bosque-Prous, Joan Colom, Cinta Folch, Tivy Barón-Garcia, Helena González-Casals, Esteve Fernández, and Albert Espelt. 2021. “Consumption of Alcohol, Cannabis, and Tobacco in a Cohort of Adolescents before and during COVID-19 Confinement.” *International Journal of Environmental Research and Public Health* 18 (15): 7849. <https://doi.org/10.3390/ijerph18157849>.

- Romano, Isabella, Karen A. Patte, Margaret De Groh, Ying Jiang, Terrance J. Wade, Richard E. Bélanger, and Scott T. Leatherdale. 2021. "Substance-Related Coping Behaviours among Youth during the Early Months of the COVID-19 Pandemic." *Addictive Behaviors Reports* 14 (December): 100392. <https://doi.org/10.1016/j.abrep.2021.100392>.
- Saulle, Rosella, Manuela De Sario, Antonella Bena, Paola Capra, Martina Culasso, Marina Davoli, Aurelia De Lorenzo, et al. 2022. "School Closures and Mental Health, Wellbeing and Health Behaviours among Children and Adolescents during the Second COVID-19 Wave: A Systematic Review of the Literature." *Epidemiologia e Prevenzione* 46 (5–6): 333–52. <https://doi.org/10.19191/EP22.5-6.A542.089>.
- Schmit, Kathryn M., Roger Brown, Supriya Hayer, Mary M. Checovich, James E. Gern, Ellen R. Wald, and Bruce Barrett. 2021. "Wisconsin Upper Respiratory Symptom Survey for Kids: Validation of an Illness-Specific Quality of Life Instrument." *Pediatric Research* 90 (6): 1207–14. <https://doi.org/10.1038/s41390-021-01395-9>.
- Shen, Zhong Hua, Yu Ming Chu, Muhammad Altaf Khan, Shabbir Muhammad, Omar A. Al-Hartomy, and M. Higazy. 2021. "Mathematical Modeling and Optimal Control of the COVID-19 Dynamics." *Results in Physics* 31 (December). <https://doi.org/10.1016/j.rinp.2021.105028>.
- Solís Arce, Julio S., Shana S. Warren, Niccolò F. Meriggi, Alexandra Scacco, Nina McMurry, Maarten Voors, Georgiy Syunyaev, et al. 2021. "COVID-19 Vaccine Acceptance and Hesitancy in Low- and Middle-Income Countries." *Nature Medicine* 27 (8): 1385–94. <https://doi.org/10.1038/s41591-021-01454-y>.
- Sonabend, Raphael, Lilith K Whittles, Natsuko Imai, Pablo N Perez-Guzman, Edward S Knock, Thomas Rawson, Katy A M Gaythorpe, et al. 2021. "Non-Pharmaceutical Interventions, Vaccination, and the SARS-CoV-2 Delta Variant in England: A Mathematical Modelling Study." *The Lancet* 398 (10313): 1825–35. [https://doi.org/10.1016/S0140-6736\(21\)02276-5](https://doi.org/10.1016/S0140-6736(21)02276-5).
- Soriano-Arandes, Antoni, Anna Gatell, Pepe Serrano, Mireia Biosca, Ferran Campillo, Ramon Capdevila, Anna Fàbrega, et al. 2021. "Household Severe Acute Respiratory Syndrome Coronavirus 2 Transmission and Children: A Network Prospective Study." *Clinical Infectious Diseases : An Official Publication of the Infectious Diseases Society of America* 73 (6): e1261–69. <https://doi.org/10.1093/CID/CIAB228>.
- Steinert, Janina I., Henrike Sternberg, Hannah Prince, Barbara Fasolo, Matteo M. Galizzi, Tim Büthe, and Giuseppe A. Veltri. 2022. "COVID-19 Vaccine Hesitancy in Eight European Countries: Prevalence, Determinants, and Heterogeneity." *Science Advances* 8 (17): 9825. <https://doi.org/10.1126/SCIADV.ABM9825>.
- Tang, Suqin, Mi Xiang, Teris Cheung, and Yu-Tao Xiang. 2021. "Mental Health and Its Correlates among Children and Adolescents during COVID-19 School Closure: The Importance of Parent-Child Discussion." *Journal of Affective Disorders* 279 (January): 353–60. <https://doi.org/10.1016/j.jad.2020.10.016>.
- Theberath, Monique, David Bauer, Weizhi Chen, Manisha Salinas, Arya B. Mohabbat, Juan Yang, Tony Y. Chon, Brent A. Bauer, and Dietlind L. Wahner-Roedler. 2022. "Effects of COVID-19 Pandemic on Mental Health of Children and Adolescents: A Systematic Review of Survey Studies." *SAGE Open Medicine* 10: 20503121221086712. <https://doi.org/10.1177/20503121221086712>.
- Tönshoff, Burkhard, Barbara Müller, Roland Elling, Hanna Renk, Peter Meissner, Hartmut Hengel, Sven F. Garbade, et al. 2021. "Prevalence of SARS-CoV-2

- Infection in Children and Their Parents in Southwest Germany.” *JAMA Pediatrics* 175 (6): 586. <https://doi.org/10.1001/jamapediatrics.2021.0001>.
- Tormos, Raül, Pau Fonseca I Casas, and Josep Maria Garcia-Alamino. 2022. “In-Person School Reopening and the Spread of SARS-CoV-2 during the Second Wave in Spain.” *Frontiers in Public Health* 10: 990277. <https://doi.org/10.3389/fpubh.2022.990277>.
- Tzur Bitan, Dana, Ariella Grossman-Giron, Yuval Bloch, Yael Mayer, Noga Shiffman, and Shlomo Mendlovic. 2020. “Fear of COVID-19 Scale: Psychometric Characteristics, Reliability and Validity in the Israeli Population.” *Psychiatry Research* 289 (July): 113100. <https://doi.org/10.1016/j.psychres.2020.113100>.
- Van Den Driessche, P., and James Watmough. 2002. “Reproduction Numbers and Sub-Threshold Endemic Equilibria for Compartmental Models of Disease Transmission.” *Mathematical Biosciences* 180 (1–2): 29–48. [https://doi.org/10.1016/S0025-5564\(02\)00108-6](https://doi.org/10.1016/S0025-5564(02)00108-6).
- Van Loon, Welmoed, Stefanie Theuring, Franziska Hommes, Marcus A. Mall, Joachim Seybold, Tobias Kurth, and Frank P. Mockenhaupt. 2021. “Prevalence of SARS-CoV-2 Infections among Students, Teachers, and Household Members during Lockdown and Split Classes in Berlin, Germany.” *JAMA Network Open*. <https://doi.org/10.1001/jamanetworkopen.2021.27168>.
- Varia, Monali, Samantha Wilson, Shelly Sarwal, Allison McGeer, Effie Gournis, Eleni Galanis, Bonnie Henry, and Hospital Outbreak Investigation Team. 2003. “Investigation of a Nosocomial Outbreak of Severe Acute Respiratory Syndrome (SARS) in Toronto, Canada.” *CMAJ: Canadian Medical Association Journal = Journal de l'Association Medicale Canadienne* 169 (4): 285–92.
- Viner, Russell M., Oliver T. Mytton, Chris Bonell, G. J. Melendez-Torres, Joseph Ward, Lee Hudson, Claire Waddington, et al. 2021. “Susceptibility to SARS-CoV-2 Infection among Children and Adolescents Compared with Adults: A Systematic Review and Meta-Analysis.” *JAMA Pediatrics* 175 (2): 143–56. <https://doi.org/10.1001/jamapediatrics.2020.4573>.
- Viswanath, K., Mesfin Bekalu, Dhriti Dhawan, Ramya Pinnamaneni, Jenna Lang, and Rachel McCloud. 2021. “Individual and Social Determinants of COVID-19 Vaccine Uptake.” *BMC Public Health* 21 (1). <https://doi.org/10.1186/s12889-021-10862-1>.
- Voysey, Merryn, Sue Ann Costa Clemens, Shabir A Madhi, Lily Y Weckx, Pedro M Folegatti, Parvinder K Aley, Brian Angus, et al. 2021. “Safety and Efficacy of the ChAdOx1 nCoV-19 Vaccine (AZD1222) against SARS-CoV-2: An Interim Analysis of Four Randomised Controlled Trials in Brazil, South Africa, and the UK.” *The Lancet* 397 (10269): 99–111. [https://doi.org/10.1016/S0140-6736\(20\)32661-1](https://doi.org/10.1016/S0140-6736(20)32661-1).
- Wallinga, J. 2004. “Different Epidemic Curves for Severe Acute Respiratory Syndrome Reveal Similar Impacts of Control Measures.” *American Journal of Epidemiology* 160 (6): 509–16. <https://doi.org/10.1093/aje/kwh255>.
- Wallinga, J, and M Lipsitch. 2007. “How Generation Intervals Shape the Relationship between Growth Rates and Reproductive Numbers.” *Proceedings of the Royal Society B: Biological Sciences* 274 (1609): 599–604. <https://doi.org/10.1098/rspb.2006.3754>.
- Wallinga, Jacco, and Peter Teunis. 2004. “Different Epidemic Curves for Severe Acute Respiratory Syndrome Reveal Similar Impacts of Control Measures.” *American Journal of EPIDEMIOLOGY*. Vol. 160. <https://academic.oup.com/aje/article/160/6/509/79472>.

- Watson, Oliver J, Gregory Barnsley, Jaspreet Toor, Alexandra B Hogan, Peter Winskill, and Azra C Ghani. 2022. “Global Impact of the First Year of COVID-19 Vaccination: A Mathematical Modelling Study.” *The Lancet Infectious Diseases* 22 (9): 1293–1302. [https://doi.org/10.1016/S1473-3099\(22\)00320-6](https://doi.org/10.1016/S1473-3099(22)00320-6).
- WHO. 2023. “Statement on the Fifteenth Meeting of the IHR (2005) Emergency Committee on the COVID-19 Pandemic.” Institutional website. www.who.int. January 5, 2023. [https://www.who.int/news/item/05-05-2023-statement-on-the-fifteenth-meeting-of-the-international-health-regulations-\(2005\)-emergency-committee-regarding-the-coronavirus-disease-\(covid-19\)-pandemic](https://www.who.int/news/item/05-05-2023-statement-on-the-fifteenth-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-coronavirus-disease-(covid-19)-pandemic).
- WHO, . World Health Organization. 2020. “Survey Tool and Guidance: Rapid, Simple, Flexible Behavioural Insights on COVID-19.” World Health Organization. Regional Office for Europe. <https://apps.who.int/iris/handle/10665/333549>.
- Wolf, Kristin, and Julian Schmitz. 2023. “Scoping Review: Longitudinal Effects of the COVID-19 Pandemic on Child and Adolescent Mental Health.” *European Child & Adolescent Psychiatry*, April, 1–56. <https://doi.org/10.1007/s00787-023-02206-8>.
- Wong, Martin C.S., Eliza L.Y. Wong, Junjie Huang, Annie W.L. Cheung, Kevin Law, Marc K.C. Chong, Rita W.Y. Ng, et al. 2021. “Acceptance of the COVID-19 Vaccine Based on the Health Belief Model: A Population-Based Survey in Hong Kong.” *Vaccine* 39 (7): 1148–56. <https://doi.org/10.1016/j.vaccine.2020.12.083>.
- World Health Organization. 2020a. “Novel Coronavirus (2019-nCoV) Situation Report - 17.” *WHO Bulletin*.
- . 2020b. “Pneumonia of Unknown Cause – China.” *Disease Outbreak News*. 2020. <https://www.who.int/csr/don/05-january-2020-pneumonia-of-unknown-cause-china/en/>.
- . n.d. “Novel Coronavirus (2019-nCoV) Situation Reports.” <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports>.
- World Health Organization (WHO). 2020. “Novel Coronavirus (2019-nCoV).” *WHO Bulletin*, no. JANUARY: 1–7.
- Yamey, Gavin, Patricia Garcia, Fatima Hassan, Wenhui Mao, Kaci Kennedy McDade, Madhukar Pai, Senjuti Saha, Philip Schellekens, Andrea Taylor, and Krishna Udayakumar. 2022. “It Is Not Too Late to Achieve Global Covid-19 Vaccine Equity.” *BMJ*, March, e070650. <https://doi.org/10.1136/bmj-2022-070650>.
- Yi, Seonju, Young-Man Kim, Young June Choe, Seonhee Ahn, Sohee Han, and Young-Joon Park. 2021. “Geospatial Analysis of Age-Specific SARS-CoV-2 Transmission Patterns in Households, Korea.” *Journal of Korean Medical Science* 36 (8). <https://doi.org/10.3346/jkms.2021.36.e63>.
- Zhang, Juanjuan, Maria Litvinova, Yuxia Liang, Yan Wang, Wei Wang, Shanlu Zhao, Qianhui Wu, et al. 2020. “Changes in Contact Patterns Shape the Dynamics of the COVID-19 Outbreak in China.” *Science* 368 (6498): 1481–86. <https://doi.org/10.1126/science.abb8001>.
- Zhong, Ns, Bj Zheng, Ym Li, Llm Poon, Zh Xie, Kh Chan, Ph Li, et al. 2003. “Epidemiology and Cause of Severe Acute Respiratory Syndrome (SARS) in Guangdong, People’s Republic of China, in February, 2003.” *The Lancet* 362 (9393): 1353–58. [https://doi.org/10.1016/S0140-6736\(03\)14630-2](https://doi.org/10.1016/S0140-6736(03)14630-2).
- Zimmerman, Kanecia O., Ibukunoluwa C. Akinboyo, M. Alan Brookhart, Angelique E. Boutzoukas, Kathleen A. McGann, Michael J. Smith, Gabriela Maradiaga Panayotti, et al. 2021. “Incidence and Secondary Transmission of SARS-CoV-2

Infections in Schools.” *Pediatrics* 147 (4): e2020048090.
<https://doi.org/10.1542/peds.2020-048090>.

ANNEX I

Syndromic surveillance as a predictive tool for health-related school absences in COVID-19 Sentinel Schools in Catalonia, Spain. (Additional article)

SUMMARY

Objective of the study: The objective of this study was to implement a syndromic surveillance strategy for children aged 6-11 years and verify the feasibility to use symptoms as predictive variables for health-related school absence in a setting of COVID-19 sentinel schools in Catalonia (CSSNC), Spain during the 2021-2022 academic year.

Study design: This is a pilot study that applied a methodology to collect data on symptomatology and school absences among elementary school children from schools participating in the CSSNC. The intervention initially involved the following steps: (i) review of validated instruments to collect respiratory symptoms and school absences adapted for children (ii) development of a short instrument for data collection among study participants, (iii) selection of schools participating in the study, (iv) application of the research in selected schools and (v) data analysis.

Study population: The study population included 135 students aged between 6 and 11 years from three primary schools in Catalonia between 16 May and 3 June 2022, spring of 2021-2022 academic year.

Data collection: Data was carried out using two short questionnaires only in paper version. The first questionnaire, addressed for the children, contained two questions about the individual daily health status and the second questionnaire was filled by the teacher to collect the number of school absences, classifying them by health reasons, by reasons not related to health and by unknown reasons.

Variables, outcome and case definitions: The first questionnaire children, contained two questions about the individual daily health status, (i) How do you feel today, in which the student could answer the following options: very well, a little sick, sick and very sick; and (ii) Do you have any of these symptoms, presented the student a list of respiratory symptoms (fever, sore throat, tiredness, runny nose, cough, sneezing and abdominal pain) on a 4-point severity scale whose options were: I don't have, a little, quite a lot, a lot. Lastly, we asked if he/she was able to answer on his/her own or needed help from someone, because this questionnaire could be filled in two different ways, with the support of the teachers/classmates and by themselves. The second questionnaire was filled

by the teacher to collect the number of school absences. We defined a school absence as the daily absence of a student at the school center not considering school trips day.

Data analysis: We performed a Latent Class Analysis (LCA) to describe potential groups of students with similar symptomatology, proceeding a cluster analysis based on multivariate binary observations. For each symptom and self-reported health was calculated the incidence rate (IR) per 100 person/day that is the number of a new reports (I) per unit of person-time at risk and the cumulative incidence, the proportion of new reports among an initially disease-free population, for the period of the study. For the univariate analysis, we proceeded a logistic mixed model with subject and school identifiers as random intercepts. Finally, we performed a multivariate analysis through a forward stepwise regression.

Results: There were enrolled in this study 135 students, representing 2163 person-days. We obtained 1536 completed surveys, 1356 (88.2%) filled by themselves (without any help). During the study period, 60 participants reported illness at least one time. The IR of new self-reported illness was 2.32 by 100 person/day, and the cumulative incidence of self-reported illness was 29.52 by 100 person/day. The 135 children generated 189 absence events during the study period, 62 (32.8%) of them related to health reasons.

The self-reported health status and symptoms were summarized in Table 3. The frequency of students that reported at least one time being sick was 44.44%, during the study period, and the overall the severity average was 1.22 in a 4-point scale. Regarding the self-reported symptoms, runny nose (75.56%), tiredness (72.59%) and cough (61.48%) were the most frequent.

We proceeded to two models with 2 and 3 latent classes to describe groups of frequent symptoms reported by the student at least once during the study period. In both models, at least one cluster was formed with a set of symptoms that resembles ILI. In the model with 2 latent classes, there is more variability between the clusters, that is, one group with few symptoms self-reported and a group with many ILI symptoms. With 3 latent classes, we can observe a group of ILI symptoms an intermediary group without sore throat and abdominal pain, and a group with few self-reported symptoms.

The association between self-reported illness overall or stratified by severity and absence was not significant. We found a significant and positive association between absence and sore throat (OR 2.23), mild sore throat (OR 2.86); moderate cough (OR 4.00); sneezing

(2.37), moderate sneezing (OR 6,06), severe sneezing (OR 4,06); and moderate abdominal pain (OR 4.00).

Syndromic surveillance as a predictive tool for health-related school absences in COVID-19 Sentinel Schools in Catalonia, Spain.

Short Title: COVID-19 Sentinel School syndromic surveillance.

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ARTICLE SUMMARY LINE

This study confirms the relevance of syndromic surveillance in students from 6 to 11 years of age as a strategy to timely detect events that can cause school absence, either to support public health actions by applying analytical models that improve their potential in providing systematized information, or to monitor and understand the health situation of students, thus offering an opportunity for rapid action.

ABSTRACT

Monitoring influenza-like illness through syndromic surveillance could be an important strategy in the COVID-19 emergence scenario. The study aims to implement syndromic surveillance for children aged 6-11 years in COVID-19 sentinel schools in Catalonia. Data collection was made by self-applied survey to collect daily health status and symptoms. We proceed logistic mixed models and a Latent Class Analysis to investigate associations with syndromes and school absence. Were enrolled 135 students (2163

person-days) that filled 1536 surveys and 60 participants reported illness (29.52 by 100 person/day) and registered 189 absence events, 62 of them (32.8%) related to health reasons. Subgroups of influenza-like illness were founded such as a significantly and positively association with school absences. The findings of this study can be applied to the detection of health events, and association with school absences, offering an opportunity for quick action, or simply for monitoring and understanding the students' health situation.

KEY WORDS: SARS-CoV-2, COVID-19, syndromic surveillance, sentinel surveillance, data analysis, school, epidemiologic studies

Introduction

Syndromic surveillance referees a complementary strategy to traditional forms of public health surveillance that aimed early detection of health events [1], faster than routine surveillance, through sensitive data supporting more effective public health actions [2–6]. This approach can have different methodologies, such as monitoring data routinely collected from ambulatorial or primary care, or, through specific systems designed to this purpose [7,8].

The main advantage of a syndromic approach is that there is no need to use data validated by medical professionals and/or laboratory diagnoses, instead, available health information is collected in near real time and can be used to report trends as quickly as possible (Lai et al. 2021). Moreover, many of data collected utilize voluntary reports and depends on human resources and an infrastructure to provide real-time analysis [5,9].

The COVID-19 pandemic brought up several challenges to the public health surveillance, regarding data collection and interpretation until changes in the health system structure, imposing to the traditional surveillance new and adapted approaches to the currently situation [10]. Thus, syndromic surveillance can use no-conventional indicators orientated to early detection [11]. Besides COVID-19, upper respiratory infections (URI) caused by several viruses such as rhinovirus, coronavirus, respiratory syncytial virus, adenovirus and influenza, have a high prevalence, especially in children [12], being a

common cause for school absence [13], and responsible for most of the healthcare visits during epidemic seasons [14].

Younger children do not have the skills to report in detail their health status, or to express themselves the potential impact on their daily routine, especially regarding clinical aspects [14]. Therefore, research of tools developed and adapted for children can serve as a guide for capturing information about mild symptoms in a population that not always seek health-care attention at the primary health level [6].

The Catalonia COVID-19 Sentinel Schools Network (CSSNC) is a project that aims to monitor and evaluate the course and effect of the COVID-19 pandemic among students, parents and staff of 23 Catalan sentinel schools. The project was consolidated through several studies that evaluated the incidence and prevalence of SARS-CoV-2 and its association with multilevel determinants, in addition to the development of associated pilot projects to validate complementary surveillance strategies aimed at this population, such as CO₂ monitoring, feasibility of public health measures and sentinel surveillance based on school absence caused by respiratory viruses. The study protocol and early results were previously published by (Bordas et al., 2022 and Ganem et al., 2022).

The planning and implementation of complementary surveillance depend on the event to be monitored, population and data available. In this case, to investigate the better approaches among sentinel school population we developed a pilot study to initially answer three questions (i) which symptoms and health conditions are most associated with school absences? (ii) the symptoms severity are the good predictors for school absence? and (iii) which analysis model can capture health events in the daily monitoring of the school sentinel population?

The objective of this study was to implement a methodology for syndromic surveillance for children aged 6-11 years and verify its application as a predictive tool for the health events and health-related school absence in a setting of COVID-19 sentinel schools in Catalonia (CSSNC), Spain during the 2021-2022 academic year.

Materials and methods

Study design and population

This is a pilot study that applied a methodology to collect data on symptomatology and school absences among elementary school children from schools participating in the CSSNC. The intervention initially involved the following steps: (i) review of validated instruments to collect respiratory symptoms and school absences adapted for children [6,11,12,14], (ii) development of a short instrument for data collection among study participants, (iii) selection of schools participating in the study, (iv) application of the research in selected schools and (v) data analysis.

The study population included 135 students aged between 6 and 11 years from three primary schools in Catalonia between 16 May and 3 June 2022, spring of 2021-2022 academic year.

Data collection, variables and outcomes

Initially, we contacted the school staff enrolled in the CSSNC to present the project, inform the procedures and invite them to participate in this specific study. Once the intention to participate was expressed, the schools were included, and a meeting was held to explain the logistics of the intervention and to select the participating classes. The schools participating in the pilot received a package containing the questionnaires and were responsible for distributing them daily to students who answered anonymously. The tutor of each class was responsible for sealing the envelopes containing the completed questionnaires, identifying them only with the name of the school, which were opened by the project members to enter the data in the REDCap project database. All data collected were anonymized.

Data collection was carried out using two short questionnaires only in paper version. The first questionnaire, addressed for the children, contained two questions about the individual daily health status, (i) How do you feel today, in which the student could answer the following options: very well, a little sick, sick and very sick; and (ii) Do you have any of these symptoms, presented the student a list of respiratory symptoms (fever, sore throat, tiredness, runny nose, cough, sneezing and abdominal pain) on a 4-point severity scale whose options were: I don't have, a little, quite a lot, a lot. Lastly, we asked if he/she was able to answer on his/her own or needed help from someone, because this questionnaire could be filled in two different ways, with the support of the teachers/classmates and by themselves. The second questionnaire was filled by the teacher

to collect the number of school absences, classifying them by health reasons, by reasons not related to health and by unknown reasons. The variables included in this study were presented in the table 1.

Table 1. Summary of variables included in the study, CSSNC, Catalonia, Spain

<i>Question/variable</i>	Coding
<i>How do you feel today?</i> ¹	Very well, a little sick, sick and very sick
Symptoms available in the questionnaire	Fever, sore throat, tiredness, runny nose, cough, sneezing and abdominal pain
<i>How severe are your symptoms?</i> ²	I don't have, a little, quite a lot, a lot (no, mild, moderate and severe)
<i>Answered on his own or needed help?</i> ³	By myself, with some help
Number of participants	N
Age range	Assumed according to the student's school cycle
Person at risk	Calculated in this study
Number of surveys applied	N
Number of surveys completed	By themselves or with help
Self-reported health status	Very well and illness (little sick, sick or very sick)
Number of participants that reported illness	N, frequency, stratified by severity and by incidence rate
Incidence rate of self-reported illness	By 100 person/day
Cumulated incidence of self-reported illness	By 100 person/day
Number of absences	By health reasons, other reasons and unknown reasons
LCA subgroups	Symptoms cluster

Original version in Catalan 1. Com et sents avui? molt bé, una mica malalt, malalt, molt malalt; 2. Tens algun d'aquests símptomes? No tinc, Una mica, Bastant, Molt and 3. He completat aquesta pàgina: Jo sol, amb una mica d'ajuda d'un company/a o mestre

We defined a school absence as the daily absence of a student at the school center. To investigate the association with symptoms, we considered that one student had an absence when he/she had not filled the questionnaire corresponding to that specific day. To validate this assumption, we calculated the total number of missing questionnaires that day and compared to the number of absences reported by the teacher, not considering school trips day.

Data analysis

We are presenting a descriptive summary of the study population characteristics, and the frequency of the outcomes. We performed a Latent Class Analysis (LCA) to describe potential groups of students with similar symptomatology. LCA consists in categorize latent subgroups, proceeding a cluster analysis based on multivariate binary observations, to reduce the number of variables [17]. First, to remove the random effect of students, we decided to aggregate the repeated measures for each participant into only one. In particular, we considered two approaches: i) to aggregate the symptoms by each week independently, that is, to have one measure for each individual which indicated whether they had each symptom one particular week, ii) to aggregate the symptoms at all study period. We choose the models with 2 and 3 latent classes since models 4 and 5 returned classes with small N and without epidemiological coherence. All these analyses were adjusted by school.

For each symptom and self-reported health status ("how do you feel today") for those who informed "a little sick", "sick" or "very sick" was calculated the incidence rate (IR) per 100 person/day that is the number of a new reports (I) per unit of person-time at risk and the cumulative incidence, the proportion of new reports among an initially disease-free population, for the period of the study, using the following equations.

$$I_r = I/\Delta T, \quad (1.1)$$

where ΔT is the total time under risk of the study population

$$CI(\Delta) = I/N_0, \quad (1.2)$$

where N_0 is the size of the initially disease-free population and I the number of new reports (incident) during the study period.

For the univariate analysis, we proceeded a logistic mixed model with subject and school identifiers as random intercepts. First, we investigated the association between one symptom and absence in the next school day, then, we investigated the association between the severity of a symptom and absence. Finally, we performed a multivariate analysis through a forward stepwise regression, but we only obtained one significant variable after selection, so we decided not to include it.

All statistical analyses had been performed in R (version 4.1.2).

Ethics approval

This study was approved on 17 December 2020 by the Ethical Committee of the Foundation University Institute for Research in Primary Health Care Jordi Gol i Gurina (IDIAPJGol) (code 20/192-PCV). Informed consent providing information about anonymity, confidentiality, use of the collected data, risks, and general information about the study, was signed for school staff, parents for those children under 16 years and student with 16 years or older. Participants were free to decline/withdraw consent at any time without providing a reason and without being subject to any resulting detriment.

Results

Regarding participation and data collected, there were enrolled in this study 135 students, representing 2163 person-days. We obtained 1536 completed surveys, 1356 (88.2%) filled by themselves (without any help). During the study period, 60 participants reported illness at least one time. The IR of new self-reported illness was 2.32 by 100 person/day, and the cumulative incidence of self-reported illness was 29.52 by 100 person/day. The 135 children generated 189 absence events during the study period, 62 (32.8%) of them related to health reasons (Table 2).

Table 2. Summary of participation and descriptive results of the syndromic surveillance pilot study, CSSNC, Catalonia, Spain, May-June 2022

Summary of participation and results	n	%
Number of participants enrolled in this study	135	100
Age range	6-11	-
Person-days ¹	2163	-
Number of surveys applied	1601	100
Number of surveys completed	1536	95.9
By themselves	1356	88.3
With help	180	11.7
Number of participants that reported feeling very well	128	-
Number of participants that reported illness (little sick, sick or very sick)	60	-
Incidence rate of self-reported illness (by 100 person/day) ²	2.32	-
Cumulated incidence of self-reported illness ³	29.52	-
Number of absences registered	189	-
For health reasons	62	32.8
For other reasons	46	24.3

1 Sum of the time-at-risk for participants overall, covering the entire study period, including weekends.

2 Incidence rate per 100 person/day is the number of a new reports per unit of person-time at risk.

3 Cumulative incidence is the proportion of new reports among an initially disease-free population.

The self-reported health status and symptoms were summarized in Table 3. The frequency of students that reported at least one time being sick was 44.44%, during the study period, and the overall the severity average was 1.22 in a 4-point scale. Regarding the self-reported symptoms, runny nose (75.56%), tiredness (72.59%) and cough (61.48%) were the most frequent (table 3).

Table 3. Occurrence, frequency and average severity of self-reported symptoms among study participants, CSSNC, Catalonia, Spain. May-June 2022.

Health related variables	Very well ¹	A little sick ¹	Sick ¹	Very sick ¹	Frequency ² (%)	Severity ³
Health status ¹						
<i>How do you feel today?</i>	174	1456	2023	2081	44.44	1.22
Self-reported symptoms ¹	No report	Mild	Moderate	Severe		
Fever	24	1951	2136	2119	14.07	1.05
Sore throat	130	1329	1971	2021	52.59	1.23
Tiredness	320	928	1725	1874	72.59	1.45
Runny nose	401	857	1726	1901	75.56	1.48
Cough	275	1191	1912	1966	61.48	1.33
Sneezing	185	1208	1951	2022	56.30	1.26
Abdominal pain	49	1663	2038	2052	37.78	1.13

1 Time at risk: summatory of time at risk for study participants overall calculated for each health status option. We calculated the risk time for each variable, that is, the period until the participants reported each health status, thus, in summary, we can interpret that the study population presented “risk of feel sick” only while they were feeling well.

2 Frequency (%): participants with score above 1 (sum of little sick, sick and very sick) at least one time during the study

3 Severity (mean) severity average in a 4-point scale average.

Latent Class Model

We proceeded to two models with 2 (fig 1a) and 3 (fig 1b) latent classes to describe groups of frequent symptoms reported by the student at least once during the study period. In both models, at least one cluster was formed with a set of symptoms that resembles ILI.

In the model with 2 latent classes, there is more variability between the clusters, that is, one group with few symptoms self-reported and a group with many ILI symptoms (2). With 3 latent classes, we can observe a group of ILI symptoms (1), an intermediary group (2) without sore throat and abdominal pain, and a group with few self-reported symptoms (3), (Fig 1a and 1b).

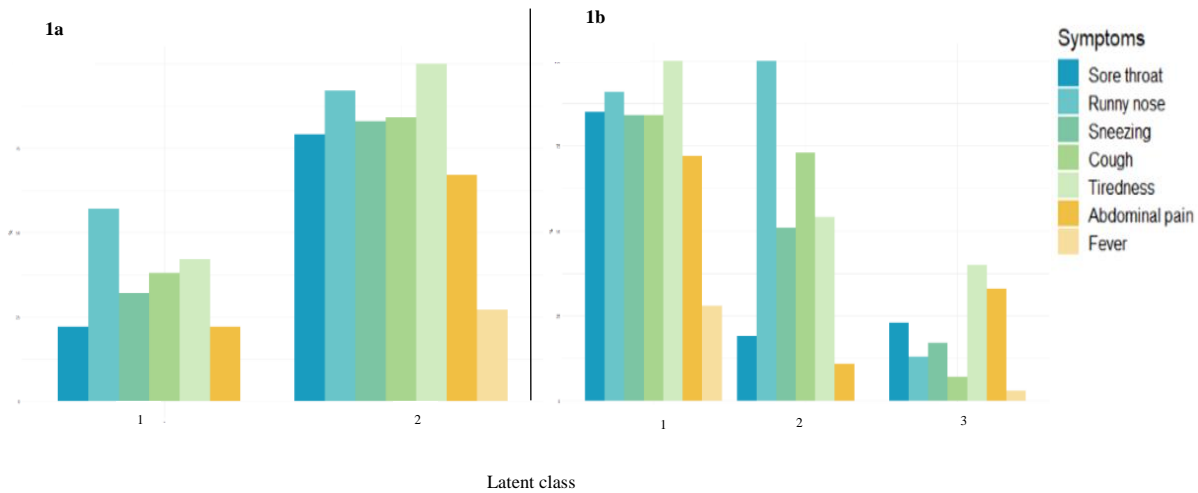


Fig 1. Graphic representation of the syndromes clusters through LCA model with (1a) two latent classes and (1b) three latent classes.

We also built the same LCA analysis through the study weeks to describe variations in clustering symptoms during the study period (Fig 2a and 2b).

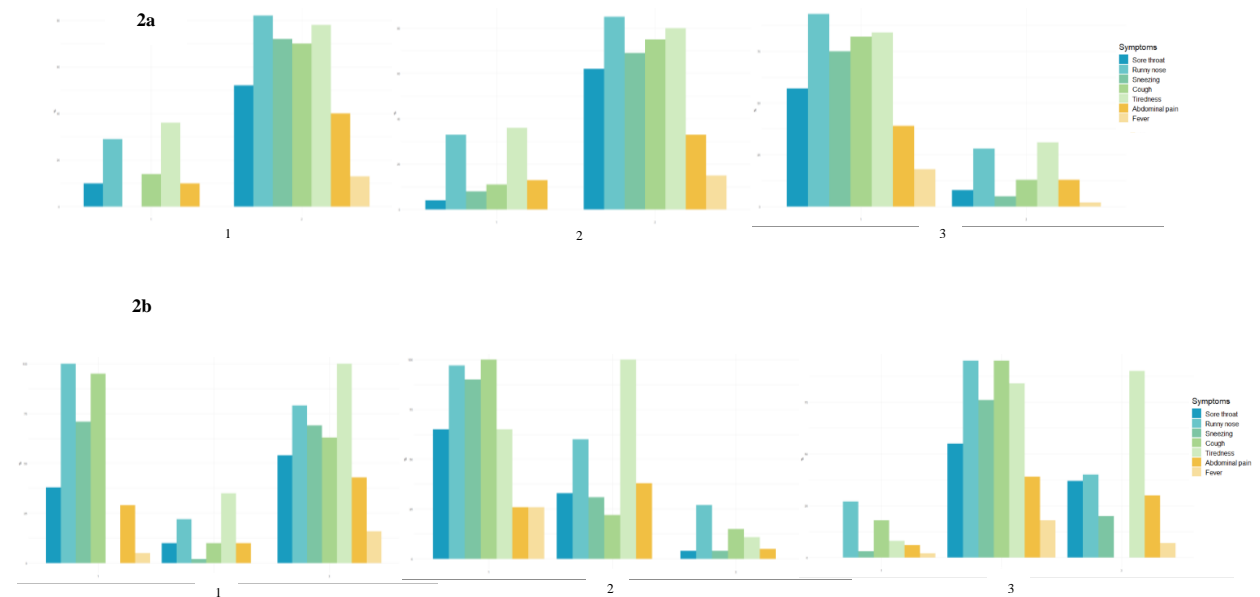


Fig 2. Weekly graphic representing changes in the syndromic cluster through LCA model with (2a) two latent classes and (2b) three latent classes.

Association between self-reported daily health status, symptoms and school absence.

The association between self-reported illness overall or stratified by severity and absence was not significant. We found a significant and positive association between absence and sore throat (OR 2.23), mild sore throat (OR 2.86); moderate cough (OR 4.00); sneezing (2.37), moderate sneezing (OR 6,06), severe sneezing (OR 4,06); and moderate abdominal pain (OR 4.00) (Table 4).

Table 4. Association between perceived daily health status, symptoms and school absence among students participating in the Sentinel School syndromic surveillance pilot study, CSSNC, Catalonia, Spain, May-June 2022.

Variables	Incidence ² (100 person/day)	CI95%	Accumulated incidence ³	CI95%	Univariate ⁴		
					OR	CI95%	P-value
Self-reported illness	2.32	1.50-3.14	29.52	20.80-38.25	1,3 6	0.74-2.46	0.321
How do you feel today?							
A little sick					1,1 3	0.55-2.27	0.744
Sick					2,7 9	0.86-8.99	0.085
Very sick					1,4 4	0.30-6.78	0.648
Symptoms							
Fever ¹	0.66	0.31-1.03	10.15	4.92-15.39	0,6 5	0.15-2.74	0.553
Mild	-	-	-	-	-	-	-
Moderate	-	-	-	-	-	-	-
Severe	-	-	-	-	-	-	-
Sore throat	3.20	2.21-4.19	38.83	29.42-48.25	2,1 1	1.18-3.77	0.011
Mild	-	-	-	-	2,8 6	1.51-5.40	0.001
Moderate and severe	-	-	-	-	1,0 0	0.34-2.91	0.993
Runny nose	4.97	3.35-6.61	52.94	41.08-64.80	1,2 6	0.77-2.04	0.351
Mild	-	-	-	-	1,0 1	0.58-1.76	0.970
Moderate	-	-	-	-	2,0 2	0.67-6.04	0.210
Severe	-	-	-	-	2,4 4	0.95-6.21	0.061

Cough	3.11	2.03-4.19	38.55	28.08-49.03	1,36	0.80-2.31	0.253
Mild	-	-	-	-	0,76	0.36-1.56	0.449
Moderate	-	-	-	-	4,00	1.67-9.56	0.002
Severe	-	-	-	-	2,07	0.69-6.11	0.190
Sneezing	2.80	1.80-3.81	34.09	24.19-43.99	2,25	1.32-3.83	0.003
Mild	-	-	-	-	1,66	0.89-3.09	0.108
Moderate	-	-	-	-	6,06	2.00-18.25	0.001
Severe	-	-	-	-	4,06	1.30-12.66	0.016
Abdominal pain	1.96	1.26-2.67	26.54	18.41-34.69	1,44	0.70-2.95	0.318
Mild	-	-	-	-	0,84	0.30-2.34	0.737
Moderate	-	-	-	-	4,00	1.15-13.88	0.029
Severe	-	-	-	-	1,99	0.42-9.43	0.384
Tiredness	5.54	3.81-7.29	52.00	40.69-63.31	1,36	0.81-2.27	0.238
Mild	-	-	-	-	1,00	0.52-1.89	0.999
Moderate	-	-	-	-	2,18	0.86-5.49	0.099
Severe	-	-	-	-	2,17	0.88-5.31	0.089

1 The model to investigate the severity did not converge, even grouping the severity in two categories.

2 Incidence rate per 100 person/day is the number of a new reports per unit of person-time at risk.

3 Cumulative incidence is the proportion of new reports among an initially disease-free population.

4 Mixed logistic model with subject and school identifiers as random intercepts.

Discussion

This study confirms the potential of a syndromic surveillance among children aged 6-11 years, as a complementary strategy to support the public health actions applying analytical models that improve their potential in providing timely and systematized information about the student's health status, symptoms and their association with school absences.

We found significantly and positively association between school absences and common cold syndrome represented by the most common symptoms reported such as sore throat, sneezing and cough. Despite being one of the most frequently reported symptoms,

tiredness was not associated with school absence, and considering that the questionnaire was applied at the end of the 21-22 academic year, this result was expected.

In this pilot study, we collected data on absences, with the support of the teacher, and on self-reported symptoms with primary school students, who answered a very simple questionnaire by themselves. Like us, other studies have also adapted tools to collect data from children, considering that they generally do not communicate their health status very well. [6,14].

The early key of this study was scaling the self-application of the survey for students of younger age groups, ensure their participation without increasing the burden of attributions of teachers and health services that have already been largely impacted by the SARS-CoV-2 pandemic. In the CSSNC project, we had already tested a self-administrated questionnaire for students over 16 years and antigen self-tests for children over 9 years, obtaining good results [16,18].

The global concern about public health emergencies demands the improvement of the strategies to monitoring the health status, risk factors and social determinants in populations at risk. It was possible, through this study, to observe a relationship between symptoms on a severity scale and school absence. We understand that the analytical model allowed us to find and explore trends of clustering of symptoms and association with the established outcome, even with a few days of monitoring, that is, it was possible to capture events within restricted periods of time. The integration of sentinel school surveillance with routine surveillance by collecting data on respiratory symptoms and school absence can help to better understand the impact of ILI in this population and to detect the occurrence of events with greater sensitivity.

The nonspecific approach of the syndromic surveillance could bring more sensibility to detecting a wider range of events and situations [19], being useful to adapt tools, promote the best approach, use and allocation of resources and ensure the best monitoring model [2,20,21]. Moreover, school absences have been already used as a tool for alerting public health events caused by influenza-like events.[6,11,13,22–25]

Considering the few number of students participants and that the exposures may occur elsewhere, we cannot extrapolate these results to the community overall. Considering the short study period, we cannot detect any seasonal variation. The strategy of syndromic surveillance must be active during a larger period, until it is possible to establish alert

limits and the specific forecast models for the target's diseases, real-time data based, for the school-age population. We were also unable to determine the health status in approximately half of the absences that were classified as by unknown reasons.

Final considerations

This article presents the potential of monitoring school absences and syndromic surveillance in a school sentinel population during the COVID-19 pandemic in Catalonia. The pilot carried out with schoolchildren shows the implementation of a strategy adapted for primary school students, with the aim of monitoring their health status in addition to contextualizing school absence by associating it with the occurrence of symptoms among the participants. In addition, the analytical plan focused on exploring the occurrence of syndromes, constructed from the grouping of these data, enabling its application for the prediction of health events, offering either an opportunity for quick action, or simply for monitoring and understanding the students' health status.

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Data sharing

All data produced in the present work are contained in the manuscript. Complementary anonymized databases and their corresponding codebooks can be available through formal proposal to the CEEISCAT via email ceeiscat@iconcologia.net. Due to legal restrictions in relation to the “Personal Information Protection Act,” personal or spatial data that allow identified any participant, including the name of the school, which was used as an adjustment factor in the analysis, cannot be made publicly available.

Conflict of interest

The authors declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author contributions

FG, CF, AB, ACC, AS and JC conceived and designed the study. ACC were responsible for the data collection; FG and LA performed the statistical and epidemiological analysis. FG wrote the first draft of the manuscript. All authors drafted the manuscript for important intellectual content, contributed to revision of the final version of the manuscript, approved the final version submitted, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. JC acts as guarantor. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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Transparency statement

The corresponding author, Cinta Folch, on behalf of the rest of the signatories, guarantees the accuracy, transparency and honesty of the data and information contained in the study; that no relevant information has been omitted; and that all discrepancies between authors/authors have been adequately resolved and described.

References

- [1] Spector E, Zhang Y, Guo Y, Bost S, Yang X, Prospero M, et al. Syndromic Surveillance Systems for Mass Gatherings: A Scoping Review. *Int J Environ Res Public Health* 2022;19:4673. <https://doi.org/10.3390/ijerph19084673>.
- [2] Colón-González FJ, Lake IR, Morbey RA, Elliot AJ, Pebody R, Smith GE. A methodological framework for the evaluation of syndromic surveillance systems: a case study of England. *BMC Public Health* 2018;18:544. <https://doi.org/10.1186/s12889-018-5422-9>.
- [3] Boyle J, Sparks R. Syndromic surveillance to detect disease outbreaks using time between emergency department presentations. *Emergency Medicine Australasia* 2022;34:92–8. <https://doi.org/10.1111/1742-6723.13907>.
- [4] Kim TH, Hong KJ, Shin S do, Park GJ, Kim S, Hong N. Forecasting respiratory infectious outbreaks using ED-based syndromic surveillance for febrile ED visits in a Metropolitan City. *Am J Emerg Med* 2019;37:183–8. <https://doi.org/10.1016/j.ajem.2018.05.007>.
- [5] KENNETH MANDL, MARC OVERHAGE, MICHAEL WAGNER, WILLIAM LOBER, PAOLA SEBASTIANI, FARZAD MOSTASHARI, et al. Implementing

Syndromic Surveillance: A Practical Guide Informed by the Early Experience. *Journal of the American Medical Informatics Association* 2003;11:141–50. <https://doi.org/10.1197/jamia.M1356>.

[6] Lai J, Hughes HE, Morbey R, Loveridge P, Lopez Bernal J, Saliba V, et al. *Epidemiology and Infection* Developing a sentinel syndromic surveillance system using school-absenteeism data, example monitoring absences over the 2020 COVID-19 pandemic. *Epidemiol Infect* 2021;149. <https://doi.org/10.1017/S0950268821002399>.

[7] Mostashari F. *Syndromic Surveillance: a Local Perspective*. *J Urban Health* 2003;80:1i–7. <https://doi.org/10.1093/jurban/jtg042>.

[8] Hiller KM, Stoneking L, Min A, Rhodes SM. *Syndromic Surveillance for Influenza in the Emergency Department—A Systematic Review*. *PLoS One* 2013;8:e73832. <https://doi.org/10.1371/journal.pone.0073832>.

[9] Bouchouar E, Hetman BM, Hanley B. *Development and validation of an automated emergency department-based syndromic surveillance system to enhance public health surveillance in Yukon: a lower-resourced and remote setting*. *BMC Public Health* 2021;21:1247. <https://doi.org/10.1186/s12889-021-11132-w>.

[10] Elliot AJ, Harcourt SE, Hughes HE, Loveridge P, Morbey RA, Smith S, et al. *The COVID-19 pandemic: a new challenge for syndromic surveillance*. *Epidemiol Infect* 2020;148:e122. <https://doi.org/10.1017/S0950268820001314>.

[11] Ward MA, Stanley A, Deeth LE, Deardon R, Feng Z, Trotz-Williams LA. *Methods for detecting seasonal influenza epidemics using a school absenteeism surveillance system*. *BMC Public Health* 2019;19:1232. <https://doi.org/10.1186/s12889-019-7521-7>.

[12] Barrett B, Brown RL, Mundt MP, Thomas GR, Barlow SK, Highstrom AD, et al. *Validation of a short form Wisconsin Upper Respiratory Symptom Survey (WURSS-21)*. *Health Qual Life Outcomes* 2009;7:76. <https://doi.org/10.1186/1477-7525-7-76>.

[13] McLean HQ, Peterson SH, King JP, Meece JK, Belongia EA. *School absenteeism among school-aged children with medically attended acute viral respiratory illness during three influenza seasons, 2012-2013 through 2014-2015*. *Influenza Other Respir Viruses* 2017;11:220–9. <https://doi.org/10.1111/irv.12440>.

- [14] Schmit KM, Brown R, Hayer S, Checovich MM, Gern JE, Wald ER, et al. Wisconsin Upper Respiratory Symptom Survey for Kids: Validation of an Illness-specific Quality of Life Instrument. *Pediatr Res* 2021;90:1207–14. <https://doi.org/10.1038/s41390-021-01395-9>.
- [15] Ganem F, Bordas A, Folch C, Alonso L, Montoro-Fernandez M, Colom-Cadena A, et al. The COVID-19 Sentinel Schools Network of Catalonia (CSSNC) project: Associated factors to prevalence and incidence of SARS-CoV-2 infection in educational settings during the 2020–2021 academic year. *PLoS One* 2022;17:e0277764. <https://doi.org/10.1371/journal.pone.0277764>.
- [16] Bordas A, Soriano-Arandes A, Subirana M, Malagrida R, Reyes-Urueña JM, Folch C, et al. Study protocol for monitoring SARS-CoV-2 infection and its determinants in Catalonia (Spain): an observational and participatory research approach in a Sentinel Network of Schools. *BMJ Open* 2022;12:e055649. <https://doi.org/10.1136/bmjopen-2021-055649>.
- [17] Beath KJ. RandomLCA: An R Package for Latent Class with Random Effects Analysis. *J Stat Softw* 2017;81. <https://doi.org/10.18637/jss.v081.i13>.
- [18] Colom-Cadena A, Martínez-Riveros H, Bordas A, Alonso-García L, Montoro-Fernández M, Romano-deGea P, et al. Feasibility of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) antigen self-testing in school and summer camp attendees. *Front Pediatr* 2023;10. <https://doi.org/10.3389/fped.2022.975454>.
- [19] Hughes HE, Edeghere O, O'Brien SJ, Vivancos R, Elliot AJ. Emergency department syndromic surveillance systems: a systematic review. *BMC Public Health* 2020;20:1891. <https://doi.org/10.1186/s12889-020-09949-y>.
- [20] Thomas MJ, Yoon PW, Collins JM, Davidson AJ, mac Kenzie WR. Evaluation of Syndromic Surveillance Systems in 6 US State and Local Health Departments. *Journal of Public Health Management and Practice* 2018;24:235–40. <https://doi.org/10.1097/PHH.0000000000000679>.
- [21] Romano S, Yusuf H, Davis C, Thomas MJ, Grigorescu V. An Evaluation of Syndromic Surveillance–Related Practices Among Selected State and Local Health Agencies. *Journal of Public Health Management and Practice* 2022;28:109–15. <https://doi.org/10.1097/PHH.0000000000001216>.

- [22] Ip D, Lau EHY, Tam YH, So T, Lam CK, Cowling BJ, et al. Evaluation of an Electronic Smart-Card Based School Absenteeism Surveillance System. *Online J Public Health Inform* 2015;Feb.
- [23] Kightlinger L, Horan V. School illness absenteeism during 2009 influenza A (H1N1) pandemic--South Dakota, 2009-2010. *S D Med* 2013;66:177, 179–81.
- [24] Lawpoolsri S, Khamsiriwatchara A, Liulark W, Taweeseeneepitch K, Sangvichean A, Thongprarong W, et al. Real-Time Monitoring of School Absenteeism to Enhance Disease Surveillance: A Pilot Study of a Mobile Electronic Reporting System. *JMIR Mhealth Uhealth* 2014;2:e22. <https://doi.org/10.2196/mhealth.3114>.
- [25] Kom Mogto CA, de Serres G, Douville Fradet M, Lebel G, Toutant S, Gilca R, et al. School Absenteeism As an Adjunct Surveillance Indicator: Experience during the Second Wave of the 2009 H1N1 Pandemic in Quebec, Canada. *PLoS One* 2012;7:e34084. <https://doi.org/10.1371/journal.pone.0034084>.