



HAL
open science

Minimizing school disruption under high incidence conditions due to the Omicron variant in France, Switzerland, Italy in January 2022

Elisabetta Colosi, Giulia Bassignana, Alain Barrat, Bruno Lina, Philippe Vanhems, Julia Bielicki, Vittoria Colizza

► To cite this version:

Elisabetta Colosi, Giulia Bassignana, Alain Barrat, Bruno Lina, Philippe Vanhems, et al.. Minimizing school disruption under high incidence conditions due to the Omicron variant in France, Switzerland, Italy in January 2022. *Eurosurveillance*, 2023, 10.2807/1560-7917.ES.2023.28.5.2200192 . hal-03971697

HAL Id: hal-03971697

<https://hal.science/hal-03971697>

Submitted on 3 Feb 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

1 **Minimizing school disruption under high incidence conditions due to the Omicron variant in France, Switzerland,**
2 **Italy in January 2022**

3 Elisabetta Colosi¹, Giulia Bassignana¹, Alain Barrat², Bruno Lina^{3,4}, Philippe Vanhems^{5,6}, Julia Bielicki⁷, Vittoria
4 Colizza¹

5 ¹Sorbonne Université, INSERM, Pierre Louis Institute of Epidemiology and Public Health, Paris, France

6 ²Aix Marseille Univ, Université de Toulon, CNRS, CPT, Turing Center for Living Systems, Marseille, France

7 ³National Reference Center for Respiratory Viruses, Department of Virology, Infective Agents Institute, Croix-
8 Rousse Hospital, Hospices Civils de Lyon, Lyon, France

9 ⁴Centre International de Recherche en Infectiologie (CIRI), Virpath Laboratory, INSERM U1111, CNRS—UMR 5308,
10 École Normale Supérieure de Lyon, Université Claude Bernard Lyon, Lyon University, Lyon, France

11 ⁵Service d'Hygiène, Épidémiologie, Infectiovigilance et Prévention, Hospices Civils de Lyon, Lyon, France

12 ⁶Centre International de Recherche en Infectiologie (CIRI), Public Health, Epidemiology and Evolutionary Ecology of
13 Infectious Diseases (PHE3ID) – Inserm - U1111 - UCBL Lyon 1 - CNRS –UMR5308 - ENS de Lyon, Lyon, France.

14 ⁷Paediatric Infectious Diseases, University of Basel Children's Hospital, Basel, Switzerland

15

16 **Background.** As record cases due to the Omicron variant were registered in Europe in early 2022, schools
17 remained a vulnerable setting suffering large disruption.

18 **Aim.** Through mathematical modelling, we compared the school protocols of reactive screening, regular screening,
19 and reactive class closure implemented in France, in Baselland (Switzerland), and in Italy, respectively, and
20 assessed them in terms of case prevention, testing resource demand, and schooldays lost.

21 **Methods.** We used a stochastic agent-based model of SARS-CoV-2 transmission in schools accounting for within-
22 class and across-class contacts from empirical contact data. We parameterized it to the Omicron BA.1 variant to
23 reproduce the French Omicron wave in January 2022. We simulated the three protocols to assess their costs and
24 effectiveness for varying peak incidence rates in the range experienced by countries in Europe.

25 **Results.** We estimated that at the high incidence rates registered in France during the Omicron BA.1 wave in
26 January 2022, the reactive screening protocol applied in France required higher test resources compared to the
27 weekly screening applied in Baselland (0.50 vs. 0.45 tests per student-week), but achieved considerably lower
28 control (8% vs. 21% of peak reduction). The reactive class closure implemented in Italy was predicted to be very
29 costly, leading to more than 20% student-days lost.

30 **Conclusions.** At high incidence conditions, a large and unplanned demand in testing resources results from
31 reactive screening protocols, for marginal control of school transmissions. Comparable or lower resources would
32 be more efficiently used through weekly screening. Our findings can be used to define incidence levels triggering
33 school protocols and optimizing their cost-effectiveness.

34

35

36

37 Introduction

38 Countries in Europe suffered large disruptions in schools at the start of 2022 due to the exceptionally high rates of
39 Omicron incidence [1]. As the adult population was largely covered by vaccination, higher incidence rates were
40 reported for the first time in children and adolescents compared to other classes [2]. In France, nearly 7,000 cases
41 per 100,000 were reported among 6-10y and 11-19y individuals at the peak of the Omicron wave in January 2022,
42 compared to about 4,500 cases per 100,000 among the 20-59y old [3]. School protocols were implemented by
43 national authorities to ensure in-person school attendance but were put under stress by the high incidence rates.
44 Protocols required repeated quarantines, disrupting attendance and learning, or led to large and sudden testing
45 demand for children, overloading saturated surveillance systems [4,5]. Through modelling, here we compared the
46 school protocols adopted by France, Switzerland, and Italy, in terms of resource peak demands, infection
47 prevention, and reduction of schooldays lost, under the high incidence conditions experienced in January 2022
48 during the Omicron BA.1 wave.

49

50 Methods

51 **Modelling SARS-CoV transmission in schools.** We adapted to the Omicron wave a stochastic agent-based model of
52 SARS-CoV-2 transmission at school presented in detail by Colosi et al. [6]. The model uses empirical data on time-
53 resolved face-to-face proximity contacts between individuals in a primary school in France, collected using
54 wearable radio frequency identification (RFID) sensors [7]. The dataset includes 232 students (aged 6–10 years)
55 and ten teachers organized in ten classes, two classes per grade. Students were found to spend on average more
56 time interacting with other students of the same class than across classes, and to establish longer contacts
57 compared to teachers [6]. We described SARS-CoV-2 infection progression through the following disease stages:
58 latency, prodromic stage, clinical and subclinical stages, recovery from infection. Stages were informed from
59 empirical distributions, and accounted for age-specific estimates of susceptibility, transmissibility, probability of
60 developing symptoms, and probability to detect a case based on symptoms [8–18].

61 We modelled the circulation of the Omicron variant, considering 20% protection after infection from prior variants
62 [19], an intrinsic transmissibility advantage of 30% relative to Delta [20], and a shorter incubation period [20,21].
63 Omicron's higher spreading rate was considered to be mainly due to immune evasion [20], in line with
64 observations from household studies [22], but we also tested a transmissibility advantage of 80% relative to Delta
65 for sensitivity. The transmissibility advantage was applied to the within-school transmissibility of previously
66 circulating variants that we inferred in prior work from observed prevalence in French schools [6]. We calibrated
67 the model to reproduce the reported community surveillance incidence in primary school students (6-10y old) in
68 France in January 2022 [23], and considered additional scenarios of Omicron waves reaching lower and higher
69 peaks to capture the variability of the wave across European countries [2]. Additional details are provided in the
70 online Supplement.

71 **School protocols.** We modelled the school protocols adopted in France, in the Baselland canton in Switzerland, and
72 in Italy. We simulated the reactive protocol applied in France in January 2022, requesting an anterior nasal lateral
73 flow device (LFD) test at days D0, D2, and D4 to the class of the detected case, following case identification [24].
74 Students with positive tests were isolated for 7 days. For sensitivity, we tested reactive screening with different
75 numbers and lags for control (D0, D3, D7 and D0, D4, see Supplement). In Baselland, students were tested on a
76 voluntary basis every week with salivary Polymerase Chain reaction (PCR) tests [25]. We thus simulated a regular
77 screening strategy, considering two options for the frequency of screening, once a week (as in Baselland), and
78 twice a week, with a 75% adherence of the school population (min-max range of 50-100%). Regular screening was
79 performed on all participating individuals, regardless of the presence of symptoms. Students with positive tests
80 were isolated for 7 days. Finally, we simulated the reactive class closure adopted in Italy, requiring a quarantine of
81 10 days for the students of the class of the detected case [26]. These protocols were considered independently in
82 the analysis, as each corresponded to a national strategy. In all cases, we also considered symptomatic testing and
83 case isolation.

84 The model was informed with time-varying and age-dependent test sensitivity, yielding an estimated 67% peak
85 sensitivity for asymptomatic children in nasal LFD tests and 96% in salivary PCR tests [27] (Supplement). We also
86 explored a lower peak sensitivity of 55% for LFD tests.

87 **Vaccination.** The model was further stratified to account for vaccination status and to include vaccine
88 effectiveness against infection and transmission (Supplement). By the first week of January 2022, 94% of adults
89 (18-59y) in France were vaccinated with at least two doses, and 45% had received the third dose since the opening
90 of the vaccination campaign on November 27, 2021 [28]. We therefore considered in the model that all teachers
91 completed the primary vaccination, with 50% of them having received also the third dose, i.e. the booster. As
92 adults were recently boosted, we considered the following values for the vaccine effectiveness (VE) against
93 infection: VE=70% for teachers vaccinated with 3 doses, corresponding to the estimate within the first 4 weeks
94 since the third dose [29]; VE=15% for those with 2 doses only, corresponding to the estimated waned efficacy at 6
95 months after the second dose [29]. For sensitivity, we varied the booster vaccination coverage in teachers up to
96 100% (Supplement).

97 The vaccination campaign in children (5-11y) opened on December 22, 2021 [30]. By mid-January 2022, the
98 coverage in this age class in France was <3% [23], therefore we assumed no vaccinated children in the main
99 analysis. We then tested higher vaccination coverages (20%, 40%, 60%) in children in the scenario analyses,
100 considering a high (VE=50%, estimated within the first 4 weeks from vaccination [31]) and low (VE=20%) values of
101 vaccine effectiveness against infection.

102

103 Results

104 Simulations capture well the reported dynamics of community surveillance incidence in primary school students
105 (6-10y) in France (**Figure 1A**). The reactive protocol implemented by authorities was predicted to marginally
106 reduce the peak, whereas regular screening would flatten more substantially the curve. The median number of
107 tests required by the reactive protocol increased along the wave, with a predicted peak demand of 0.50
108 (interquartile range IQR 0.32 – 0.71) tests per student per week at the incidence rate experienced in France (**Figure**
109 **1C**). Test demand instead was predicted to decrease in the regular protocols because fewer students would be
110 present in class after the peak of infections due to isolation (0.45 (IQR 0.42 – 0.47) tests in the once-a-week
111 screening and 0.96 (IQR 0.91 – 1.02) in the twice-a-week screening). We found that higher incidence conditions
112 could lead to a larger demand of tests by the reactive protocol compared to the weekly screening (**Figure 1BD**).

113 To evaluate how to best use resources, we estimated the impact of protocols in reducing the peak incidence and
114 extended the analysis of **Figure 1** to a larger set of Omicron wave scenarios with varying peak incidence. For the
115 incidence rates registered in France in January 2022, reactive screening was estimated to lower the peak by 8%
116 (IQR -3% – 19%), compared to 21% (IQR 11% – 31%) reduction achieved by the weekly screening (**Figure 2AB**),
117 despite the higher demand in testing resources at the peak (0.50 vs. 0.45 tests per student-week, respectively).
118 The predicted number of tests required by the reactive screening would increase for increasing values of the
119 incidence rate (from 0.31 to 0.65 tests per student-week corresponding to 5,000 to 10,700 cases per 100,000), but
120 they would achieve a marginal control of the viral circulation at school, reducing the peak of the wave by at most
121 12%. Results would not change by changing the lags of the reactive screening (D0, D3, D7 vs. D0, D2, D4) but peak
122 reduction would be even lower if a lower number of screenings was adopted (D0, D4; Supplement). Regular
123 screening would instead achieve 20% or more of peak reduction for incidence rates up to 7,500 cases per 100,000
124 with a weekly frequency, and for rates up to 10,100 cases per 100,000 if screening the school twice a week. Similar
125 results were obtained considering the reduction of the epidemic size of the full wave and a higher transmissibility
126 advantage of the Omicron variant (Supplement).

127 Student-days lost remained below 12% with reactive and weekly screening, whereas reactively closing the class as
128 in the Italian protocol could lead to >20% of absence per student if peak incidence is over 7,500 cases per 100,000
129 (**Figure 2C**). Findings were robust against changes in booster coverage in teachers, in Omicron transmissibility and
130 incubation period (Supplement). Higher detection rates would penalize the reactive screening, due to an increase
131 in test demand while control would remain limited (Supplement).

132 Changing from nasal LFD tests to salivary PCR tests would improve the reactive strategy from 8% to 13% peak
133 reduction if results were available after 12h (**Figure 3A**). Instead, regular testing was predicted to be mainly
134 affected by adherence to screening (**Figure 3B**). Vaccinating 6-10y old children was predicted to provide a
135 collective benefit in reducing viral circulation at school. If children were vaccinated close to the epidemic wave
136 (therefore with an estimated vaccine effectiveness $VE=50\%$ for children within 4 weeks after the second dose), the
137 peak would be reduced by approximately 30% for 40% coverage and by approximately 40% for 60% coverage,
138 compared to no vaccination (**Figure 3C**). If vaccination occurred long before the epidemic wave (waned vaccine
139 effectiveness $VE=20\%$), the reductions would be smaller, around 15% and 20% for 40% and 60% coverage,
140 respectively.

141

142 **Discussion**

143 For the high incidence rates recorded in January 2022 in Europe due to the Omicron BA.1 variant, our study
144 predicted that reactive screening strategies in schools, as employed in France, required a higher number of tests
145 per student per week compared to weekly screening, but achieved a lower epidemic control. The protocol
146 requesting three tests in less than a week for case contacts in French primary schools led to large disruption events
147 in January 2022, in terms of logistics, resources, and impact on surveillance capacity [4]. We estimated that the
148 same resources would have been more efficiently used by weekly screening schools, reaching 21% peak reduction
149 for the incidence rates registered in France in January 2022, compared to the marginal reduction (8%) estimated
150 for the reactive screening.

151 Reactive screening is predicted to be poorly effective in case prevention for two main reasons. First, timely
152 interventions of case identification and isolation are key to control SARS-CoV-2 diffusion, given the presence of
153 pre-symptomatic and subclinical transmission [32]. Reactive strategies suffer from considerable time lags
154 compared to the ongoing transmission dynamics. Second, this aspect is particularly challenging in children as they
155 have a lower probability of developing symptoms [12,13,15,17,33], and therefore of being identified as possible
156 COVID-19 cases compared to adults. By the time the screening is activated, after the detection of a case based on
157 recognizable symptoms, the transmission may have already occurred in the school and have previously generated
158 asymptomatic infections that went unnoticed. That is, the case triggering the screening does not necessarily
159 represent the start of the chain of transmission, and may instead occur after few generations of cases that are not
160 discovered by surveillance, or following undetected introductions. On the contrary, regularly screening the school
161 every week or twice a week allows the prompt identification and isolation of infectious individuals regardless of
162 their symptoms [6,33–40]. As more cases are found, onward transmissions are more efficiently prevented, with a
163 higher efficiency if frequency of screening is higher. The capacity of screening (whether reactive or proactive) to
164 reduce the peak incidence decreases for increasing values of the incidence rates. Higher incidence in the
165 community indeed corresponds to larger rates of introductions in the school, which require an even more rapid
166 response for the identification of cases to prevent onward transmission [6].

167 Some countries opted for systematically screening schools against SARS-CoV-2 transmission, supported by
168 numerical evidence [6,33–40]. Authorities in Baselland (Switzerland) offered weekly salivary PCR tests to all
169 schools since March 2021. Prior to making participation mandatory in 2022, recorded adherence was on average
170 rather high (>75%) [25]. Proactively screening also has the advantage of planning resources in advance, contrary to
171 reactive screening subject to sudden peak demands and potential shortages. This was reported to help simplifying
172 the logistics of test-to-stay strategies in pilot weekly screenings implemented in a number of pre-primary and
173 primary schools in the Auvergne-Rhône-Alpes region in France in December 2021. Preliminary unpublished
174 empirical estimates from these screenings also suggest a reduction of cases during the Delta wave in December
175 2021 compared to the reactive strategy, in line with model predictions.

176 The widespread access to nasal antigenic tests made repeated self-testing possible without loss in efficiency, as
177 lower sensitivity is compensated by promptness of results and high frequency [41]. Regular self-testing would also
178 limit the high rates of absence from school that are associated to reactive class closures. Without test
179 confirmation, reactively closing the class imposes the quarantine to likely uninfected students who would
180 unnecessarily miss school while transmission may have already occurred in other classes due to cross-classes
181 contacts or through introductions [6]. Under the high incidence rates registered in the Omicron wave, our model

182 predicted multiple class closures continuously disrupting the school rhythm and impacting students' learning, with
183 more than 20% of schooldays lost per student, compatible with observations in Italy during that wave [5].

184 This study focused exclusively on the school setting, and did not assess the impact that protocols at schools, aimed
185 at limiting school transmission, may have on the epidemic dynamics in the community. Model-based findings
186 previously highlighted that protocols mitigating viral circulation at school also reduce the spread in the community
187 [35,42,43]. Conversely, increased transmission in the community was found to be associated to schools in session
188 [44,45], and households with children were estimated to be at higher risk of SARS-CoV-2 infection [46], suggesting
189 that a considerable fraction of transmission events originated from the school setting [47]. The analysis of a school
190 outbreak in early 2021 in a municipality in the North of Italy estimated that approximately 21% of SARS-CoV-2
191 transmissions were associated with school contacts, compared to 50% and 29% transmissions associated with
192 household and community contacts, respectively [48]. Combined with the above evidence, our findings therefore
193 suggest that implementing strategies to control transmission at school will reduce the potential for seeding
194 transmissions from schools to other settings, narrowing the spread across households [49] and the risk of reaching
195 individuals at risk of complications.

196 As European countries approach the third winter of the COVID-19 pandemic, our findings can be used to tune the
197 response by defining incidence levels triggering protocols if facing a high incidence wave, depending on the
198 severity of the circulating variant and according to the objectives established by authorities. Systematically
199 screening schools remains the optimal test-to-stay strategy, reducing peak incidence rates in children, and thus
200 their consequences on hospitalizations [50] and long COVID [51] in this age class, while limiting school disruption
201 and requested resources. Large vaccination coverage in children contributes to mitigate high viral circulation,
202 making schools safer. Coverage remains however low in children in several European countries (16% median
203 coverage for 2-dose vaccination in 5-9y old by the start of September 2022; Supplement).

204 Our study has limitations. We did not consider immunity waning over time as we focused on a single pandemic
205 wave, but tested low vaccine effectiveness to account for the estimated reduction associated with the lag from the
206 last vaccination dose. Our results are framed within the context experienced by European countries. As such,
207 results are not directly applicable to other countries with a context of lower immunity due to the limited spread of
208 earlier variants. In previous work, however, we showed that conclusions are qualitatively robust, with regular
209 screening strategies outperforming reactive strategies in case prevention under a set of different epidemic and
210 immunization conditions [6].

211 A large demand in tests results from reactively screening schools in high incidence conditions. Comparable
212 resources could be more efficiently used in a proactive screening strategy to mitigate the peak.

215 **Ethical statement**

216 Ethical approval was not needed for this study.

218 **References**

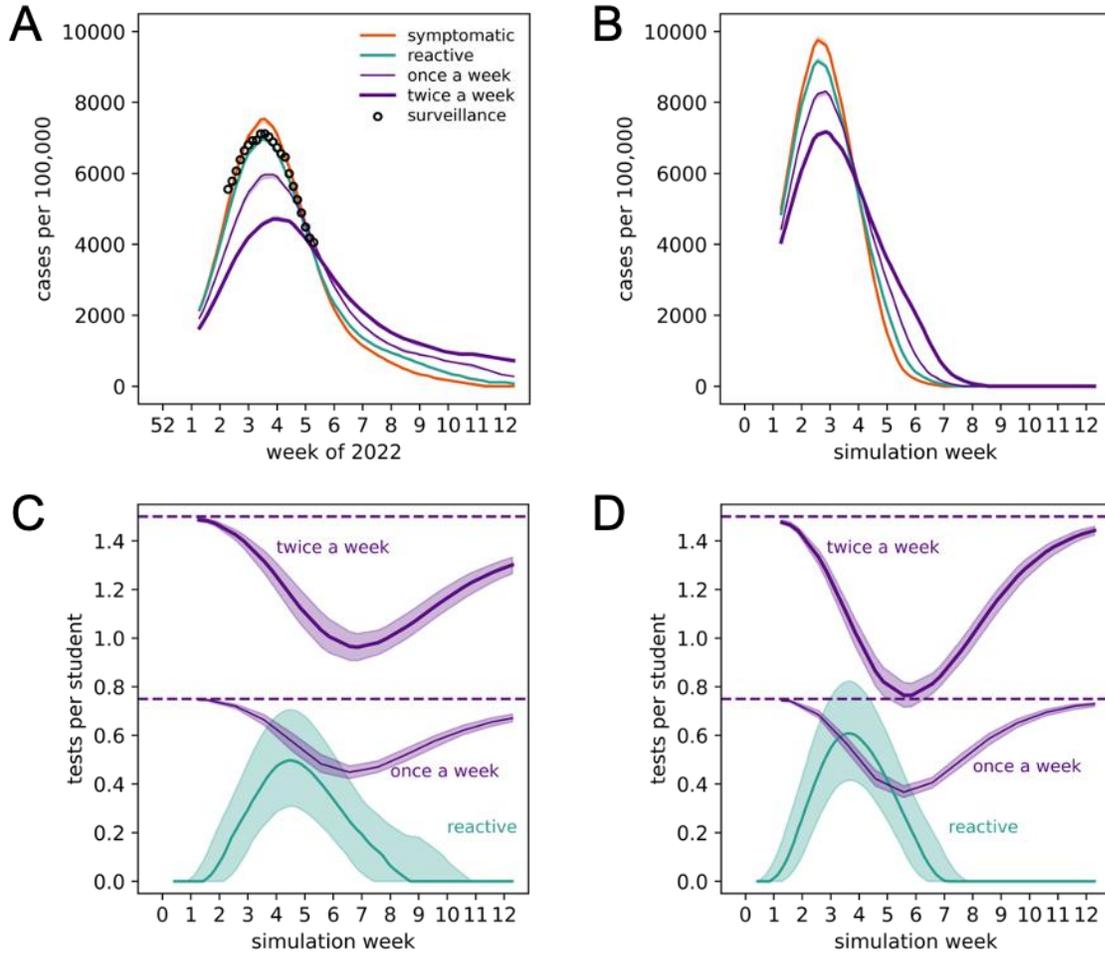
- 219 [1] ECDC. Country overview report: week 3 2022. European Centre for Disease Prevention and Control 2022.
220 <https://www.ecdc.europa.eu/en/covid-19/country-overviews> (accessed February 1, 2022).
- 221 [2] ECDC-WHO. Joint ECDC-WHO Regional Office for Europe Weekly COVID-19 Surveillance Bulletin. European
222 Centre for Disease Prevention and Control and World Health Organization; 2021.
- 223 [3] Géodes - Santé publique France - Indicateurs : cartes, données et graphiques n.d.
224 [https://geodes.santepubliquefrance.fr/#c=indicator&f=29&i=sp_heb.tx_pe_hebdo&s=2022-](https://geodes.santepubliquefrance.fr/#c=indicator&f=29&i=sp_heb.tx_pe_hebdo&s=2022-S41&t=a01&view=map2)
225 [S41&t=a01&view=map2](https://geodes.santepubliquefrance.fr/#c=indicator&f=29&i=sp_heb.tx_pe_hebdo&s=2022-S41&t=a01&view=map2) (accessed October 25, 2022).
- 226 [4] Morin V, Battaglia M, Rof G, Mayer C, Beaudouin A, Triolier G, et al. Covid-19 : dans les écoles, la semaine de
227 toutes les tensions. Le Monde 2022.
- 228 [5] Fregonara G. Più che raddoppiate le classi in Dad. Medie e superiori, si torna senza tampone. Corriere della
229 Sera 2022. [https://www.corriere.it/scuola/secondaria/22_gennaio_28/raddoppiano-classi-dad-20-cento-](https://www.corriere.it/scuola/secondaria/22_gennaio_28/raddoppiano-classi-dad-20-cento-studenti-casa-81a371d0-802f-11ec-9fac-a85f17701932.shtml)
230 [studenti-casa-81a371d0-802f-11ec-9fac-a85f17701932.shtml](https://www.corriere.it/scuola/secondaria/22_gennaio_28/raddoppiano-classi-dad-20-cento-studenti-casa-81a371d0-802f-11ec-9fac-a85f17701932.shtml) (accessed February 1, 2022).

- 231 [6] Colosi E, Bassignana G, Contreras DA, Poirier C, Boëlle P-Y, Cauchemez S, et al. Screening and vaccination
232 against COVID-19 to minimise school closure: a modelling study. *The Lancet Infectious Diseases*
233 2022;22:977–89. [https://doi.org/10.1016/S1473-3099\(22\)00138-4](https://doi.org/10.1016/S1473-3099(22)00138-4).
- 234 [7] Fournet J, Barrat A. Contact Patterns among High School Students. *PLOS ONE* 2014;9:e107878.
235 <https://doi.org/10.1371/journal.pone.0107878>.
- 236 [8] Viner RM, Mytton OT, Bonell C, Melendez-Torres GJ, Ward J, Hudson L, et al. Susceptibility to SARS-CoV-2
237 Infection Among Children and Adolescents Compared With Adults: A Systematic Review and Meta-analysis.
238 *JAMA Pediatrics* 2021;175:143. <https://doi.org/10.1001/jamapediatrics.2020.4573>.
- 239 [9] Fontanet A, Tondeur L, Grant R, Temmam S, Madec Y, Bigot T, et al. SARS-CoV-2 infection in schools in a
240 northern French city: a retrospective serological cohort study in an area of high transmission, France,
241 January to April 2020. *Eurosurveillance* 2021;26:2001695. <https://doi.org/10.2807/1560-7917.ES.2021.26.15.2001695>.
- 242 [10] Thompson HA, Mousa A, Dighe A, Fu H, Arnedo-Pena A, Barrett P, et al. Severe Acute Respiratory Syndrome
243 Coronavirus 2 (SARS-CoV-2) Setting-specific Transmission Rates: A Systematic Review and Meta-analysis.
244 *Clinical Infectious Diseases* 2021. <https://doi.org/10.1093/cid/ciab100>.
- 245 [11] Luo L, Liu D, Liao X, Wu X, Jing Q, Zheng J, et al. Contact Settings and Risk for Transmission in 3410 Close
246 Contacts of Patients With COVID-19 in Guangzhou, China. *Ann Intern Med* 2020;173:879–87.
247 <https://doi.org/10.7326/M20-2671>.
- 248 [12] Davies NG, Klepac P, Liu Y, Prem K, Jit M, Eggo RM. Age-dependent effects in the transmission and control of
249 COVID-19 epidemics. *Nature Medicine* 2020;26:1205–11. <https://doi.org/10.1038/s41591-020-0962-9>.
- 250 [13] Riccardo F, Ajelli M, Andrianou XD, Bella A, Manso MD, Fabiani M, et al. Epidemiological characteristics of
251 COVID-19 cases and estimates of the reproductive numbers 1 month into the epidemic, Italy, 28 January to
252 31 March 2020. *Eurosurveillance* 2020;25:2000790. <https://doi.org/10.2807/1560-7917.ES.2020.25.49.2000790>.
- 253 [14] Shekerdemian LS, Mahmood NR, Wolfe KK, Riggs BJ, Ross CE, McKiernan CA, et al. Characteristics and
254 Outcomes of Children With Coronavirus Disease 2019 (COVID-19) Infection Admitted to US and Canadian
255 Pediatric Intensive Care Units. *JAMA Pediatr* 2020;174:868.
256 <https://doi.org/10.1001/jamapediatrics.2020.1948>.
- 257 [15] Dong Y, Mo X, Hu Y, Qi X, Jiang F, Jiang Z, et al. Epidemiology of COVID-19 Among Children in China.
258 *Pediatrics* 2020;145. <https://doi.org/10.1542/peds.2020-0702>.
- 259 [16] Dattner I, Goldberg Y, Katriel G, Yaari R, Gal N, Miron Y, et al. The role of children in the spread of COVID-19:
260 Using household data from Bnei Brak, Israel, to estimate the relative susceptibility and infectivity of children.
261 *PLOS Computational Biology* 2021;17. <https://doi.org/10.1371/journal.pcbi.1008559>.
- 262 [17] Han MS, Choi EH, Chang SH, Jin B-L, Lee EJ, Kim BN, et al. Clinical Characteristics and Viral RNA Detection in
263 Children With Coronavirus Disease 2019 in the Republic of Korea. *JAMA Pediatrics* 2021;175:73.
264 <https://doi.org/10.1001/jamapediatrics.2020.3988>.
- 265 [18] Smith LE, Potts HWW, Amlôt R, Fear NT, Michie S, Rubin GJ. Adherence to the test, trace, and isolate system
266 in the UK: results from 37 nationally representative surveys. *BMJ* 2021;372:n608.
267 <https://doi.org/10.1136/bmj.n608>.
- 268 [19] Ferguson N, Ghani A, Cori A, Hogan A, Hinsley W, Volz E. Report 49: Growth, population distribution and
269 immune escape of Omicron in England. Imperial College London; 2021. <https://doi.org/10.25561/93038>.
- 270 [20] Faes C, Willem L, Franco N, Hens N, Beutels P, Abrams S. SARS-CoV-2 variants and vaccination in Belgium.
271 *SIMID consortium*; 2022.
- 272 [21] Jansen L, Tegomoh B, Lange K, Showalter K, Figliomeni J, Abdalhamid B, et al. Investigation of a SARS-CoV-2
273 B.1.1.529 (Omicron) Variant Cluster — Nebraska, November–December 2021. *MMWR Morb Mortal Wkly*
274 *Rep* 2021;70. <https://doi.org/10.15585/mmwr.mm705152e3>.
- 275 [22] Lyngse FP, Kirkeby CT, Denwood M, Christiansen LE, Mølbak K, Møller CH, et al. Household transmission of
276 SARS-CoV-2 Omicron variant of concern subvariants BA.1 and BA.2 in Denmark. *Nat Commun* 2022;13:5760.
277 <https://doi.org/10.1038/s41467-022-33498-0>.
- 278 [23] Géodes - Santé publique France - Indicateurs : cartes, données et graphiques n.d.
279 <https://geodes.santepubliquefrance.fr/#view=map2&c=indicator> (accessed April 12, 2021).
- 280 [24] Ministère de l'Éducation Nationale de la Jeunesse et des Sports. Année scolaire 2021-2022 : protocole
281 sanitaire et mesures de fonctionnement. Ministère de l'Éducation Nationale de la Jeunesse et des Sports n.d.
282
283

- 284 [https://www.education.gouv.fr/annee-scolaire-2021-2022-protocole-sanitaire-et-mesures-de-](https://www.education.gouv.fr/annee-scolaire-2021-2022-protocole-sanitaire-et-mesures-de-fonctionnement-324257)
285 [fonctionnement-324257](https://www.education.gouv.fr/annee-scolaire-2021-2022-protocole-sanitaire-et-mesures-de-fonctionnement-324257) (accessed January 20, 2022).
- 286 [25] Basel Landschaft. Covid-19 Breites Testen BL. baselland.ch n.d. [https://www.baselland.ch/politik-und-](https://www.baselland.ch/politik-und-behorden/direktionen/volkswirtschafts-und-gesundheitsdirektion/amt-fur-gesundheit/medizinische-dienste/kantonsarztlicher-dienst/aktuelles/covid-19-faelle-kanton-basel-landschaft/covid-19-breites-testen-bl)
287 [behorden/direktionen/volkswirtschafts-und-gesundheitsdirektion/amt-fur-gesundheit/medizinische-](https://www.baselland.ch/politik-und-behorden/direktionen/volkswirtschafts-und-gesundheitsdirektion/amt-fur-gesundheit/medizinische-dienste/kantonsarztlicher-dienst/aktuelles/covid-19-faelle-kanton-basel-landschaft/covid-19-breites-testen-bl)
288 [dienste/kantonsarztlicher-dienst/aktuelles/covid-19-faelle-kanton-basel-landschaft/covid-19-breites-testen-](https://www.baselland.ch/politik-und-behorden/direktionen/volkswirtschafts-und-gesundheitsdirektion/amt-fur-gesundheit/medizinische-dienste/kantonsarztlicher-dienst/aktuelles/covid-19-faelle-kanton-basel-landschaft/covid-19-breites-testen-bl)
289 [bl](https://www.baselland.ch/politik-und-behorden/direktionen/volkswirtschafts-und-gesundheitsdirektion/amt-fur-gesundheit/medizinische-dienste/kantonsarztlicher-dienst/aktuelles/covid-19-faelle-kanton-basel-landschaft/covid-19-breites-testen-bl) (accessed February 2, 2022).
- 290 [26] MIUR. Nota tecnica - Indicazioni per l'individuazione e la gestione dei contatti di casi di infezione da SARS-
291 CoV-2 in ambito scolastico. Ministero dell'Istruzione Ministero dell'Università e della Ricerca 2021.
292 [https://www.miur.gov.it/documents/20182/0/Nota+tecnica+-](https://www.miur.gov.it/documents/20182/0/Nota+tecnica+-+Indicazioni+per+l%E2%80%99individuazione+e+la+gestione+dei+contatti+di+casi+di+infezione+da+SARS-CoV-2+in+ambito+scolastico.pdf/838ef7ff-225c-2cbe-f3b8-a90448e10fc9?version=1.0&t=1636204411355)
293 [+Indicazioni+per+l%E2%80%99individuazione+e+la+gestione+dei+contatti+di+casi+di+infezione+da+SARS-](https://www.miur.gov.it/documents/20182/0/Nota+tecnica+-+Indicazioni+per+l%E2%80%99individuazione+e+la+gestione+dei+contatti+di+casi+di+infezione+da+SARS-CoV-2+in+ambito+scolastico.pdf/838ef7ff-225c-2cbe-f3b8-a90448e10fc9?version=1.0&t=1636204411355)
294 [CoV-2+in+ambito+scolastico.pdf/838ef7ff-225c-2cbe-f3b8-a90448e10fc9?version=1.0&t=1636204411355](https://www.miur.gov.it/documents/20182/0/Nota+tecnica+-+Indicazioni+per+l%E2%80%99individuazione+e+la+gestione+dei+contatti+di+casi+di+infezione+da+SARS-CoV-2+in+ambito+scolastico.pdf/838ef7ff-225c-2cbe-f3b8-a90448e10fc9?version=1.0&t=1636204411355)
295 (accessed February 1, 2022).
- 296 [27] Smith RL, Gibson LL, Martinez PP, Ke R, Mirza A, Conte M, et al. Longitudinal Assessment of Diagnostic Test
297 Performance Over the Course of Acute SARS-CoV-2 Infection. *The Journal of Infectious Diseases*
298 2021;224:976–82. <https://doi.org/10.1093/infdis/jiab337>.
- 299 [28] Covid-19 : dose de rappel, pass sanitaire, ce qu'il faut retenir des annonces d'Olivier Véran. ici, par France
300 Bleu et France 3 2021. [https://www.francebleu.fr/infos/sante-sciences/direct-covid-19-suivez-l-intervention-](https://www.francebleu.fr/infos/sante-sciences/direct-covid-19-suivez-l-intervention-d-olivier-veran-1637769888)
301 [d-olivier-veran-1637769888](https://www.francebleu.fr/infos/sante-sciences/direct-covid-19-suivez-l-intervention-d-olivier-veran-1637769888) (accessed October 24, 2022).
- 302 [29] Kirsebom FCM, Andrews N, Stowe J, Toffa S, Sachdeva R, Gallagher E, et al. COVID-19 vaccine effectiveness
303 against the omicron (BA.2) variant in England. *The Lancet Infectious Diseases* 2022;22:931–3.
304 [https://doi.org/10.1016/S1473-3099\(22\)00309-7](https://doi.org/10.1016/S1473-3099(22)00309-7).
- 305 [30] service-public.fr. La vaccination est possible pour tous les enfants de 5 à 11 ans avec l'accord d'un seul
306 parent. Service-Public.fr Le site officiel de l'administration française 2022. [https://www.service-](https://www.service-public.fr/particuliers/actualites/A15393)
307 [public.fr/particuliers/actualites/A15393](https://www.service-public.fr/particuliers/actualites/A15393) (accessed October 26, 2022).
- 308 [31] Cocchio S, Zabeo F, Tremolada G, Facchin G, Venturato G, Marcon T, et al. COVID-19 Vaccine Effectiveness
309 against Omicron Variant among Underage Subjects: The Veneto Region's Experience. *Vaccines*
310 2022;10:1362. <https://doi.org/10.3390/vaccines10081362>.
- 311 [32] Ferretti L, Wymant C, Kendall M, Zhao L, Nurtay A, Abeler-Dörner L, et al. Quantifying SARS-CoV-2
312 transmission suggests epidemic control with digital contact tracing. *Science* 2020;368.
313 <https://doi.org/10.1126/science.abb6936>.
- 314 [33] Flasche S, Edmunds WJ. The role of schools and school-aged children in SARS-CoV-2 transmission. *The Lancet*
315 *Infectious Diseases* 2021;21:298–9. [https://doi.org/10.1016/S1473-3099\(20\)30927-0](https://doi.org/10.1016/S1473-3099(20)30927-0).
- 316 [34] McGee RS, Homburger JR, Williams HE, Bergstrom CT, Zhou AY. Model-driven mitigation measures for
317 reopening schools during the COVID-19 pandemic. *PNAS* 2021;118.
318 <https://doi.org/10.1073/pnas.2108909118>.
- 319 [35] Liu Q-H, Zhang J, Peng C, Litvinova M, Huang S, Poletti P, et al. Model-based evaluation of alternative
320 reactive class closure strategies against COVID-19. *Nat Commun* 2022;13:322.
321 <https://doi.org/10.1038/s41467-021-27939-5>.
- 322 [36] Endo (遠藤彰) A, CMMID COVID-19 Working Group, Uchida (内田満夫) M, Liu (刘扬) Y, Atkins KE, Kucharski
323 AJ, et al. Simulating respiratory disease transmission within and between classrooms to assess pandemic
324 management strategies at schools. *Proceedings of the National Academy of Sciences*
325 2022;119:e2203019119. <https://doi.org/10.1073/pnas.2203019119>.
- 326 [37] Leng T, Hill EM, Holmes A, Southall E, Thompson RN, Tildesley MJ, et al. Quantifying pupil-to-pupil SARS-CoV-
327 2 transmission and the impact of lateral flow testing in English secondary schools. *Nat Commun*
328 2022;13:1106. <https://doi.org/10.1038/s41467-022-28731-9>.
- 329 [38] Lasser J, Sorger J, Richter L, Thurner S, Schmid D, Klimek P. Assessing the impact of SARS-CoV-2 prevention
330 measures in Austrian schools using agent-based simulations and cluster tracing data. *Nat Commun*
331 2022;13:554. <https://doi.org/10.1038/s41467-022-28170-6>.
- 332 [39] Torneri A, Willem L, Colizza V, Kremer C, Meuris C, Darcis G, et al. Controlling SARS-CoV-2 in schools using
333 repetitive testing strategies. *ELife* 2022;11:e75593. <https://doi.org/10.7554/eLife.75593>.

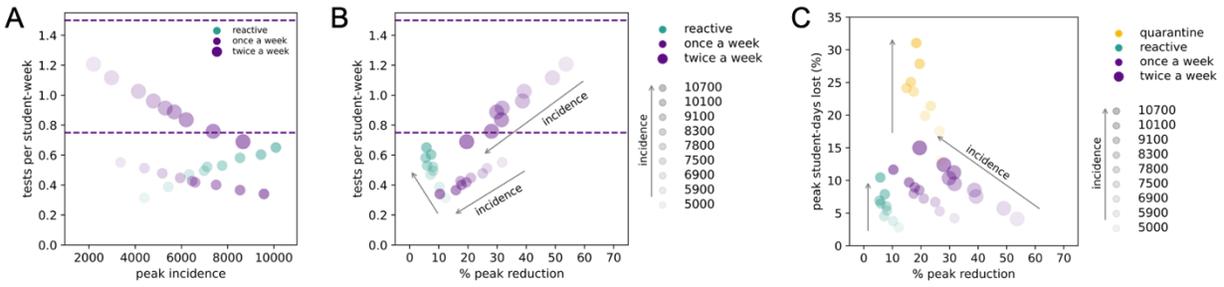
- 334 [40] Paltiel AD, Zheng A, Walensky RP. Assessment of SARS-CoV-2 Screening Strategies to Permit the Safe
335 Reopening of College Campuses in the United States. *JAMA Netw Open* 2020;3:e2016818.
336 <https://doi.org/10.1001/jamanetworkopen.2020.16818>.
- 337 [41] Larremore DB, Wilder B, Lester E, Shehata S, Burke JM, Hay JA, et al. Test sensitivity is secondary to
338 frequency and turnaround time for COVID-19 surveillance. *MedRxiv* 2020:2020.06.22.20136309.
339 <https://doi.org/10.1101/2020.06.22.20136309>.
- 340 [42] Di Domenico L, Pullano G, Sabbatini CE, Boëlle P-Y, Colizza V. Modelling safe protocols for reopening schools
341 during the COVID-19 pandemic in France. *Nat Commun* 2021;12:1073. <https://doi.org/10.1038/s41467-021-21249-6>.
- 342
- 343 [43] Rozhnova G, van Dorp CH, Bruijning-Verhagen P, Bootsma MCJ, van de Wijgert JHHM, Bonten MJM, et al.
344 Model-based evaluation of school- and non-school-related measures to control the COVID-19 pandemic. *Nat*
345 *Commun* 2021;12:1614. <https://doi.org/10.1038/s41467-021-21899-6>.
- 346 [44] Goldstein E, Lipsitch M, Cevik M. On the Effect of Age on the Transmission of SARS-CoV-2 in Households,
347 Schools, and the Community. *J Infect Dis* 2021;223:362–9. <https://doi.org/10.1093/infdis/jiaa691>.
- 348 [45] Li Y, Campbell H, Kulkarni D, Harpur A, Nundy M, Wang X, et al. The temporal association of introducing and
349 lifting non-pharmaceutical interventions with the time-varying reproduction number (R) of SARS-CoV-2: a
350 modelling study across 131 countries. *The Lancet Infectious Diseases* 2021;21:193–202.
351 [https://doi.org/10.1016/S1473-3099\(20\)30785-4](https://doi.org/10.1016/S1473-3099(20)30785-4).
- 352 [46] Galmiche S, Charmet T, Schaeffer L, Paireau J, Grant R, Chény O, et al. Exposures associated with SARS-CoV-2
353 infection in France: A nationwide online case-control study. *The Lancet Regional Health - Europe* 2021;7.
354 <https://doi.org/10.1016/j.lanepe.2021.100148>.
- 355 [47] Meuris C, Kremer C, Geerinck A, Locquet M, Bruyère O, Defêche J, et al. Transmission of SARS-CoV-2 After
356 COVID-19 Screening and Mitigation Measures for Primary School Children Attending School in Liège,
357 Belgium. *JAMA Netw Open* 2021;4:e2128757. <https://doi.org/10.1001/jamanetworkopen.2021.28757>.
- 358 [48] Manica M, Poletti P, Deandrea S, Mosconi G, Ancarani C, Lodola S, et al. Estimating SARS-CoV-2 transmission
359 in educational settings: A retrospective cohort study. *Influenza Resp Viruses* 2022:irv.13049.
360 <https://doi.org/10.1111/irv.13049>.
- 361 [49] Iersel SCJL van, Backer JA, Gaalen RD van, Andeweg SP, Munday JD, Wallinga J, et al. Empirical evidence of
362 transmission over a school-household network for SARS-CoV-2; exploration of transmission pairs stratified
363 by primary and secondary school 2022:2022.02.12.22270851.
364 <https://doi.org/10.1101/2022.02.12.22270851>.
- 365 [50] Nyberg T, Ferguson NM, Nash SG, Webster HH, Flaxman S, Andrews N, et al. Comparative analysis of the
366 risks of hospitalisation and death associated with SARS-CoV-2 omicron (B.1.1.529) and delta (B.1.617.2)
367 variants in England: a cohort study. *The Lancet* 2022;399:1303–12. [https://doi.org/10.1016/S0140-6736\(22\)00462-7](https://doi.org/10.1016/S0140-6736(22)00462-7).
- 368
- 369 [51] Stephenson T, Stephenson T, Pereira SP, Shafran R, Stavola BD, Rojas N, et al. Long COVID - the physical and
370 mental health of children and non-hospitalised young people 3 months after SARS-CoV-2 infection; a
371 national matched cohort study (The CLoCk) Study. *Research Square* 2021. <https://doi.org/10.21203/rs.3.rs-798316/v1>.
- 372
- 373
- 374

375 FIGURES
 376
 377
 378



379
 380 **Figure 1. Incidence and number of tests per student over time under different school protocols, France, January**
 381 **2022.** A: simulated weekly incidence expressed in number of cases in students per 100,000 over time for different
 382 protocols, and reported incidence in the 6-10y age class in France in the period 10/01 – 06/02/2022 [23]. The
 383 reactive protocol, applied in France, is calibrated to surveillance data. B: as in A for simulated scenarios at higher
 384 introduction conditions. C,D: average number of tests per student over time for reactive and regular protocols
 385 under the epidemic conditions illustrated in the top panels. The horizontal dashed lines indicate the theoretical
 386 values of the demands in number of tests per student in the screening once a week and twice a week (i.e. imposed
 387 by 75% adherence and by the frequency). Results are obtained considering the use of nasal LFD tests in both
 388 reactive and regular screenings. Shaded areas around the curves correspond to the interquartile range (IQR).
 389

390



391

392

393

394

395

396

397

398

399

400

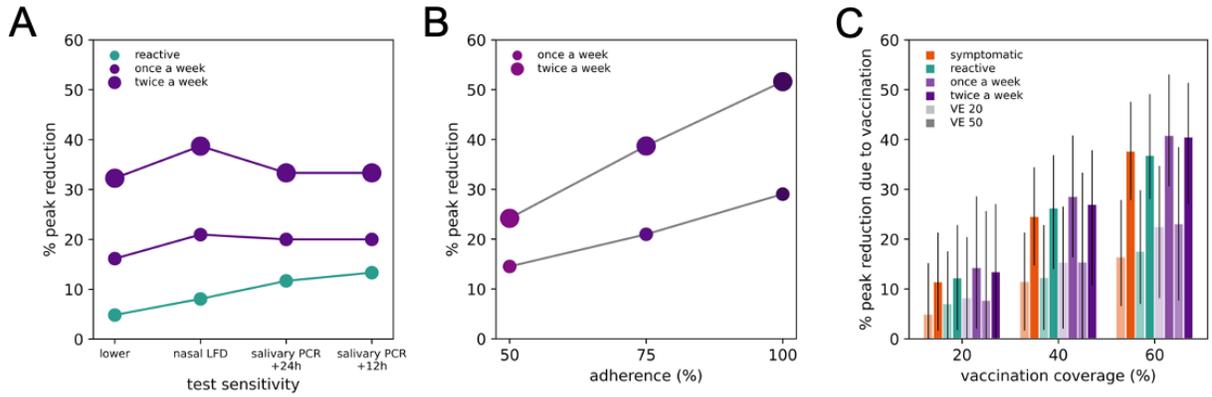
401

402

403

Figure 2. Test needs and schooldays lost vs. peak reduction at varying peak incidence rates. A: Demand in the number of tests per student-week at peak as a function of the peak incidence (cases in students per 100,000) for the reactive protocol and the regular screening protocols with once a week and twice a week frequency. The horizontal dashed lines indicate the theoretical values of the number of tests per student in the regular screening (i.e. imposed by 75% adherence and the frequency). Dots reduce their transparency for increasing incidence. B: Demand in the number of tests per student-week at peak as a function of the percentage of peak reduction achieved by each protocol compared to symptomatic testing (i.e. in absence of interventions), for different incidence levels. The horizontal dashed lines are as in panel A. Dots transparency code is the same as in panel A. C: Peak percentage of student-days lost as a function of the percentage of peak reduction achieved by each protocol compared to symptomatic testing, for different incidence levels. The reactive quarantine of the class is shown as an additional protocol. Arrows are shown as guide to the eye.

404



405

406

407

408

409

410

411

412

Figure 3. Impact of test sensitivity, adherence to regular screening, and vaccination. A: Percentage of peak reduction achieved by each protocol compared to symptomatic testing (i.e. in absence of interventions) as a function of the test sensitivity and of the delay in returning the results (+12h, +24h for PCR tests). The lower value corresponds to 55% peak sensitivity. B: Percentage of peak reduction as a function of adherence to regular screening. C: Reduction (%) in the peak incidence for each protocol due to vaccination in children, for different vaccination coverages for vaccine effectiveness VE=50% (solid bars) and VE=20% (transparent bars). Results of all panels refer to the Omicron wave shown in Figure 1A.

413

414

415

416

417

418

419

420

421

422

423

424

425

426

427

428

429

430

431

432