School closures during COVID-19: an overview of systematic reviews

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Abstract

Objectives To assess the benefits and drawbacks of school closures and in-school mitigations during the COVID-19 pandemic.

Design Overview of systematic reviews (SRs).

Search methods We searched six databases and additional resources on 29 July 2022: MEDLINE, Embase, Google Scholar, Cochrane Library, COVID-END inventory of evidence synthesis, and Epistemonikos.

Eligibility criteria We selected SRs written in English that answered at least one of four specific questions concerning the efficacy and drawbacks of school closures. Their primary studies were conducted in primary and secondary schools, including pupils aged 5–18. Interventions included school closures or mitigations (such as mask usage) introduced in schools.

Data collection and analysis We used AMSTAR 2 to assess confidence in the included SRs, and GRADE was used to assess certainty of evidence. We performed a narrative synthesis of the results, prioritising higher-quality SRs, those which performed GRADE assessments and those with more unique primary studies. We also assessed the overlap between primary studies included in the SRs.

Main outcome measures Our framework for summarising outcome data was guided by the following questions: (1) What is the impact of school closures on COVID-19 transmission, morbidity or mortality in the community? (2) What is the impact of COVID-19 school closures on mental health (eg, anxiety), physical health (eg, obesity, domestic violence, sleep) and learning/achievement of primary and secondary pupils? (3) What is the impact of mitigations in schools on COVID-19 transmission, morbidity or mortality in the community? and (4) What is the impact of COVID-19 mitigations in schools on mental health, physical health and learning/achievement of primary and secondary pupils?

Results We identified 578 reports, 26 of which were included. One SR was of high confidence, 0 moderate, 10 low and 15 critically low confidence. We identified 132 unique primary studies on the effects of school closures on transmission/morbidity/mortality, 123 on learning, 164 on mental health, 22 on physical health, 16 on sleep, 7 on domestic violence and 69 on effects of in-school mitigations on transmission/morbidity/mortality.

Both school closures and in-school mitigations were associated with reduced COVID-19 transmission, morbidity and mortality in the community. School closures were also associated with reduced learning, increased anxiety and increased obesity in pupils. We found no SRs that assessed potential drawbacks of in-school mitigations on pupils. The certainty of evidence according to GRADE was mostly very low.

Conclusions School closures during COVID-19 had both positive and negative impacts. We found a large number of SRs and primary studies.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ COVID-19 has caused millions of global deaths since the end of 2019, and has seen unprecedented levels of public health intervention, including school closures, to reduce its transmission. However, the effectiveness of school closures in reducing transmission is still not fully understood. Similarly, potential negative effects on children have not been fully characterised.

WHAT THIS STUDY ADDS

⇒ We performed an overview of systematic reviews to address these knowledge gaps. Evidence suggests a positive effect of school closures in reducing COVID-19 transmission, but also negative impacts. Children were reported to suffer reduced learning, increased anxiety and increased obesity. Our study's limitations include that the specific impacts of school closures are difficult to separate from other interventions introduced simultaneously, that we have reviewed a lack of data on Omicron variants, and that we were unable to perform meta-analysis.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This overview may inform pandemic planning policymakers when considering the benefits and harms of school closures during potential future waves of COVID-19.

However, confidence in the SRs was mostly low to very low, and the certainty of evidence was also mostly very low. We found no SRs assessing the potential drawbacks of in-school mitigations on children, which could be addressed moving forward. This overview provides evidence that could inform policy makers on school closures during future potential waves of COVID-19.

Introduction

COVID-19 has caused worldwide morbidity and mortality, requiring pharmaceutical and non-pharmaceutical interventions (NPIs) to control its spread.[1] These NPIs include mask-wearing, social distancing and school closures, all of which have been employed in most countries multiple times since the onset of the COVID-19 pandemic.[2]

SARS-CoV-2, the virus that causes COVID-19, is highly transmissible and mutable, and has produced a number of variants of concern. Most recent is Omicron and its subvariants, which are more immune-evasive and more transmissible than previous strains.[3 4] These variants have caused worldwide records of COVID-19 infection, and induced further school closures.[5] The likely emergence of new variants in the future, causing new periods of exponential growth, means that school closures may continue to be considered by governments around the world.

The aim of school closures is to reduce social contacts, to cut transmission chains in the community.[2] However, their effectiveness remains uncertain, and whether the positive impacts of school closures on transmission outweigh potential negative impacts on children remains unknown. Despite most countries shutting schools during the COVID-19 pandemic, closures were generally not part of pandemic planning,[6 7] and it is unclear whether the potential negative impacts were fully considered by policymakers.

The number of systematic reviews (SRs) on COVID-19 school closures, which have addressed this topic from multiple angles—with varying quality, and with conclusions that are not always consistent—provides an opportunity for an evidence synthesis from a wider perspective. Given this, we decided that an overview of SRs was the best study type.

Methods

The protocol for this overview was registered in February 2022.[8] We conducted the overview in line with Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines (https://prisma-statement.org/), and with guidelines for reporting overviews.[9–12]

Data sources

We searched MEDLINE via PubMed, Embase via Ovid, Google Scholar, the Cochrane Database of Systematic Reviews, COVID-END inventory of evidence synthesis, and Epistemonikos, on 29 July 2022. References of included SRs were also handsearched.

Search strategy

PubMed - COVID-19 [tiab] AND (school* [tiab] OR college* [tiab]). Filter by article type: systematic review or meta-analysis.

Embase - (COVID-19 AND (school* OR college*)).tw. Limit search to: systematic review or meta-analysis.

Google scholar - allintitle: "COVID-19" "systematic review" school OR schools OR college OR colleges.

Cochrane library - COVID-19 AND (school OR college). Limit search to Title Abstract Keyword, limit to Cochrane Reviews.

Epistemonikos - Filter by COVID-19 evidence, school congregate setting, systematic review.

COVID-END - Evidence about economic and social responses: Education section.

Inclusion and exclusion criteria

Only SRs (including rapid reviews) were included. Given the range of SRs published on this topic, whose results are not always consistent, we agreed that an overview of SRs was the best study design for a wide perspective on the topic. Only texts written in English were included, because we felt that we could not fairly review SRs written in other languages. Only SRs that answer at least one of the following four questions were included:

1. What is the impact of school closures (compared with no intervention) on COVID-19 transmission, morbidity or mortality of people in the community?
2. What is the impact of school closures (compared with no intervention or pre-COVID-19 levels) on mental health (eg, anxiety), physical health (eg, obesity, domestic violence, sleep) and learning/achievement of primary and secondary pupils (aged 5–18)?
3. What is the impact of mitigations in schools (compared with no intervention) on COVID-19 transmission, morbidity or mortality of people in the community?
4. What is the impact of mitigations in schools (compared with no intervention or pre-COVID-19 levels) on mental health, physical health and learning/achievement of primary and secondary pupils (aged 5–18)?

Definition of terms

School closures: Shutting of education institutions for 5–18 year olds, during the COVID-19 pandemic, resulting in students staying at home. In-school mitigations: Measures introduced to schools to reduce COVID-19 transmission, such as mask-wearing, social distancing and isolation of positive COVID-19 cases. Transmission: spreading of SARS-CoV-2 from human to human, usually measured by PCR positivity, R-value or secondary attack rate. Morbidity: COVID-19-induced hospitalisation. Mortality: COVID-19-induced death. Impact: Effect on transmission/morbidity/mortality or on students; for example, on mental health (eg, anxiety), physical health (eg, obesity) or learning and achievement (eg, test scores). SR: A study that searches more than one database to answer a defined question, includes at least two primary studies answering that question, and identifies itself as an SR/meta-analysis/rapid review in the title. The study must be a full journal article (and not, eg, a conference abstract or protocol).

Study selection

Our search found 578 studies (452 initially and 126 in the updated search), which were imported into Mendeley. A total of 242 duplicates were removed, and screening was performed using the Rayyan software.[13] Articles were independently screened by two authors (SH and SRB), by title, abstract and full text, according to our inclusion and exclusion criteria, and 26 SRs were ultimately included in the overview (figure 1). Disagreements were resolved by discussion between all authors.

Data extraction

Two authors (SH and SRB) independently performed data extraction, according to a predefined data extraction table (online supplemental table 1). Data extracted were first author/year, main questions asked in the study, study type, study period, search strategy, number of included studies, quality appraisal tool used,
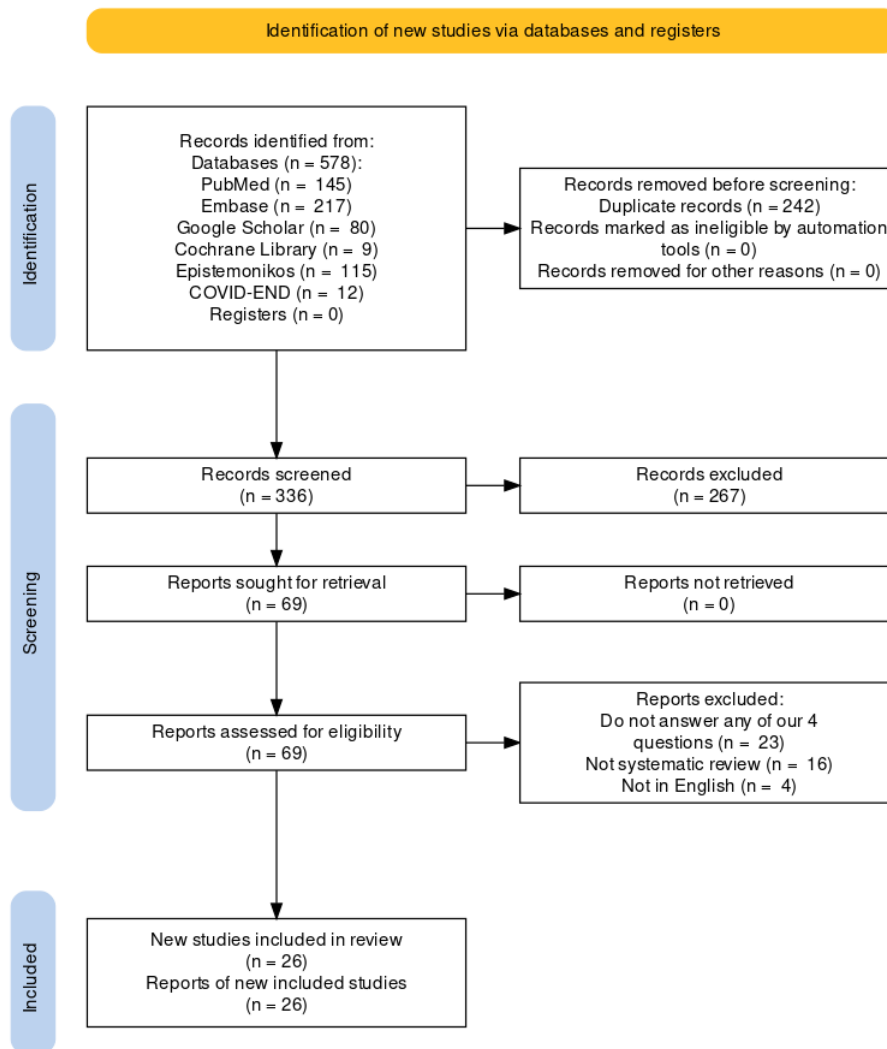
Figure 1 Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow diagram. A full list of excluded studies is provided in online supplemental table 2.

authors' assessment on quality of included studies, main conclusions, funding/conflicts of interest, journal and which of our four posed questions the study addresses. Geographical areas covered in each SR, and the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) assessment performed by each SR, were later added.

Quality assessment

The AMSTAR 2 (A MeaSurement Tool to Assess systematic Reviews 2) tool was used, which contains 16 criteria to assess the quality of SRs[14] (table 1).

Critical domains in the AMSTAR 2 tool are as follows. Item (2) Has the protocol been preregistered, and is the protocol comprehensive? Item (4) Is the literature search comprehensive? Item (7) Is a list of excluded studies provided, with exclusion reasons? Item (9) Is an appropriate risk of bias analysis performed? Item (11) Are the statistical analysis used in any meta-analysis appropriate? Item (13) Is the risk of bias considered when synthesising review results? Item (15) Is publication bias considered in studies that perform quantitative analysis?

SRs with 0 or 1 non-critical weakness were rated as high quality, studies with multiple non-critical weaknesses as medium,

SRs with 1 critical weakness as low and SRs with multiple critical weaknesses as critically low.[14]

Data synthesis

A narrative synthesis was performed. Each outcome was divided into independent sections in the Results section—for example, when assessing the impact of school closures on pupils, mental health was described in its own Results section. Within each Results section, SRs were described in order of quality (based on AMSTAR 2 assessments), with the highest quality SRs described first. SRs were then prioritised based on those that performed GRADE assessments (online supplemental table 1), and subsequently based on those that contained a higher proportion of unique primary studies (online supplemental table 3). Higher-quality SRs were given more weight in concluding each outcome. Data were drawn from SR authors' conclusions and results, and additional details, such as quantification from meta-analysis, were also added if available. Our findings were summarised in table 2.

GRADE assessments

For each outcome, GRADE assessments were used to assess the certainty of evidence.[15 16] GRADE ratings from included SRs were

Table 1 AMSTAR 2 quality appraisal

Authors	PICO clear	Protocol registered*	Included study designs explained	Comprehensive search strategy*	Duplicate screening	Duplicate data extraction	Excluded studies listed*	Full description of included studies	RoB assessed*	Funding of included studies stated	Appropriate statistics (in MA)*	RoB considered (in MA)	RoB considered in interpretation*	Explanation of heterogeneity	Publication bias considered (in MA)*	Conflict of interest declared	Rating
Zhang et al, 2021[31]	+	-	+	Partial+	+	+	-	+	+	-	+	+	+	+	+	+	Critically low
NCCMT, 2021[17]	+	-	+	Partial+	-	-	+	+	+	-	N/A	N/A	-	-	N/A	+	Critically low
Walsh et al, 2021[18]	+	+	+	Partial+	+	+	-	+	+	-	N/A	N/A	+	+	N/A	+	Low
Kourti et al, 2021[41]	+	-	+	Partial+	+	+	-	+	+	-	N/A	N/A	-	+	N/A	+	Critically low
Ayouni et al, 2021[20]	+	Partial+	+	Partial+	+	+	-	+	+	-	N/A	N/A	+	+	N/A	+	Low
Talic et al, 2021[21]	+	Partial+	+	Partial+	+	+	-	+	+	-	+	+	+	+	+	+	Low
Hammerstein et al, 2021[28]	+	-	+	Partial+	+	-	-	+	+	-	N/A	N/A	-	+	N/A	+	Critically low
Muhammed, 2020[22]	+	-	+	Partial+	-	-	-	-	-	-	N/A	N/A	-	+	N/A	-	Critically low
Bond et al, 2021[30]	+	-	+	Partial+	+	-	+	+	+	-	N/A	N/A	+	+	N/A	+	Low
Sharma et al, 2021[40]	+	Partial+	+	Partial+	+	+	-	+	+	-	+	+	-	+	+	+	Critically low
Krishnaratne et al, 2022[42]	+	Partial+	+	Partial+	+	+	+	+	+	+	N/A	N/A	+	+	N/A	+	High
Elharake et al, 2022[32]	+	-	+	Partial+	+	+	-	+	-	-	N/A	N/A	-	-	N/A	+	Critically low
Meherali et al, 2021[33]	+	Partial+	+	Partial+	+	+	-	+	+	-	N/A	N/A	+	+	N/A	+	Low
Nussbaumer-Streit et al, 2020[23]	+	Partial+	+	+	+	+	-	+	+	-	N/A	N/A	+	+	N/A	+	Low
Samji et al, 2021[34]	+	Partial+	+	Partial+	+	+	-	+	+	-	N/A	N/A	+	+	N/A	+	Low
Viner et al, 2020[24]	+	-	+	Partial+	+	-	-	-	-	-	N/A	N/A	-	+	N/A	+	Critically low
Viner et al, 2022[35]	+	Partial+	+	+	+	+	-	+	+	-	N/A	N/A	+	+	N/A	+	Low
Lehmann et al, 2022[36]	+	-	+	Partial+	+	+	-	+	+	-	N/A	N/A	+	+	N/A	-	Critically low
Panagouli et al, 2021[29]	+	-	+	Partial+	+	+	-	+	+	-	N/A	N/A	+	+	N/A	+	Critically low
Mendez-Brito et al, 2021[25]	+	-	+	Partial+	+	-	-	+	+	-	N/A	N/A	+	+	N/A	+	Critically low
Chaabane et al, 2021[26]	+	Partial+	+	Partial+	+	+	-	+	+	-	N/A	N/A	+	+	N/A	+	Low
Chai et al, 2021[37]	+	+	-	Partial+	-	-	-	+	+	-	+	+	+	+	+	+	Low
Suk et al, 2020[27]	+	-	+	Partial+	+	+	-	+	-	-	N/A	N/A	-	+	N/A	-	Critically low
Vardavas et al, 2021[43]	+	-	+	Partial+	+	+	-	+	-	-	N/A	N/A	-	+	N/A	+	Critically low
Chang et al, 2021[39]	+	-	-	Partial+	+	+	-	+	+	-	+	+	+	+	+	+	Critically low
Caini et al, 2022[19]	+	-	+	Partial+	-	+	-	+	+	-	+	+	+	+	+	+	Critically low

Stars indicate critical domains. SRs with 0 or 1 non-critical flaw score 'High', studies with multiple non-critical flaws score 'Medium', studies with 1 critical flaw score 'Low' and studies with multiple critical flaws score 'Critically low'. SRs are awarded a '+' or '-' depending on whether they satisfy each condition. SRs are awarded a Partial+ in 'Protocol registered' if they register a protocol, but no register a protocol, and a Partial+ in 'comprehensive search strategy' if, for example, authors search at least two databases, but no not scan included articles' bibliographies. Full details of the AMSTAR 2 appraisal tool are available at Shea et al.[14]

AMSTAR 2, A MeaSurement Tool to Assess systematic Reviews 2; MA, meta-analysis; NA, not applicable.; PICO, Population, Intervention, Comparison, Outcome; RoB, risk of bias;

Table 2 Summary of findings

Question	Unique primary studies	Outcome	Result	Magnitude of effect	GRADE
1: What is the effect of school closures on community COVID-19 transmission, morbidity and mortality?	132	Transmission	Reduced: 6 SRs[20–23 25 27] (closures) Uncertain: 2 SRs[18 19] (closures) No effect: 2 SRs[17 18] (re-openings)	▶ Transmission from pupils less likely than from adults (OR 0.26, 95% CI (0.11 to 0.63))[19] (Meta-analysis) ▶ Pupils may be less likely to be infected than adults (OR 0.6, 95% CI (0.25 to 1.47))[19] (Meta-analysis)	Very low* ⊕◯◯◯
		Hospitalisation	Reduced: 1 SR[26]	▶ 45% reduction in paediatric hospital admissions[26]	Very low† ⊕◯◯◯
		Mortality	Reduced: 1 SR[24]	▶ 2%–4% reduction in deaths[24]	Very low‡ ⊕◯◯◯
2: What is the effect of school closures on children's health?	123	Learning	Worse: 4 SRs[26 28–30]	▶ Learning loss of −0.005 to −0.05 SD, per week of closures[28]	Low ⊕⊕◯◯
	164	Mental health	Worse: 8 SRs[26 31–37]	▶ Prevalence of anxiety during COVID-19: 24% (95% CI (20% to 29%))[31] (Meta-analysis) ▶ Anxiety in outbreak phase: 25% (95% CI (17% to 34%))[31] (Meta-analysis) ▶ Anxiety in diffusion attenuation phase: 42% (95% CI (35% to 50%))[31] (Meta-analysis) ▶ Prevalence of mental health problems during COVID-19: 28% (95% CI (22% to 34%))[37] (Meta-analysis)	Very low§ ⊕◯◯◯
	22	Physical health	Worse: 3 SRs[26 35 39]	▶ BMI increased by 0.77 units (95% CI (0.33 to 1.2)) p=0.0006), obesity prevalence by 1.23-fold (95% CI (1.1 to 1.37)) p=0.0002), and bodyweight by 2.67 kg (95% CI (2.12 to 3.23)) p<0.00001[39] (Meta-analysis)	Very low¶ ⊕◯◯◯
	16	Sleep	Worse: 2 SRs[35 40] No effect: 1 SR[26]	▶ 54% (95% CI (50% to 57%)) had sleep disturbance[40] (Meta-analysis) ▶ 49% (95% CI (39% to 58%)) did not achieve recommended sleep quantities[40] (Meta-analysis)	Very low** ⊕◯◯◯
	7	Domestic violence	Increased: 1 SR[41] Uncertain: 1 SR[35]	▶ 67% reduction in reported cases of domestic violence involving children[41] ▶ 41% reduction in police reports for domestic violence involving children[41] ▶ Estimated increase in victims of violence against children: 11 488 186–18 381 098 in Africa, 3 577 839–5 724 542 in Asia, 2 921 466–4 674 345 in Latin America, 7 59 600–1 215 360 in Europe, 2 009 722–3 215 554 in North America, and 32 010–51 216 in Oceania[41]	Very low†† ⊕◯◯◯
3: What is the effect of in-school mitigations on community COVID-19 transmission, morbidity or mortality?	69	Transmission	Reduced: 3 SRs[17 42 43]	▶ Mask usage in schools associated with reduction in R in community by 0.011 (95% CI (0.008 to 0.0127))[42]	Very low‡‡ ⊕◯◯◯
		Hospitilisation	Reduced: 1 SR[42]	▶ Mask usage in schools associated with reduction in excess hospitalisation per 10 000 of population in teachers to 4.2 (95% CI (−47.39 to 48.09)) from 40.5 (95% CI (−46.95 to 146.64))[42]	Very low§§ ⊕◯◯◯
		Mortality	Reduced: 1 SR[42]	▶ Mask usage in schools associated with reduction in community mortality by ratio of 1.5 (95% CI (1.5 to 1.6))[42]	Very low¶¶ ⊕◯◯◯
4: What is the effect of in-school mitigations on children's health?	0	Children's health	0 SRs	Not available	–

Number of unique studies in individual SRs. For question 1 - [20]: 2, [21]: 3, [22]: 5, [23]: 4, [25]: 15, [27]: 3, [26]: 1, [24]: 4, [17]: 14, [18]: 25, [19]: 34. For question 2 (learning) - [28]: 1, [30]: 77, [29]: 29, [26]: 3. For question 2 (mental health) - [31]: 7, [32]: 0, [33]: 3, [34]: 103, [35]: 15, [36]: 8, [26]: 1, [37]: 5. For question 2 (physical health) - [35]: 7, [26]: 2, [39]: 12. For question 2 (sleep) - [40]: 6, [35]: 6, [26]: 0. For question 2 (domestic violence) - [41]: 4, [35]: 2. For question 3 - [17]: 17, [42]: 38, [43]: 14.

Data from meta-analysis were prioritised to represent effect measures for each outcome, where available.

*Downgraded for risk of bias and inconsistency.
†Downgraded for imprecision.
‡Downgraded for imprecision and risk of bias.
§Downgraded for risk of bias.
¶Downgraded for risk of bias.
**Downgraded for inconsistency and imprecision.
††Downgraded for indirectness.
‡‡Downgraded for indirectness and imprecision.
§§Downgraded for risk of bias, indirectness and imprecision.
¶¶Downgraded for risk of bias, indirectness and imprecision.
BMI, body mass index; GRADE, Grading of Recommendations, Assessment, Development and Evaluations.

used if they were the only SR assessing that outcome, and if sufficient justification was given for the GRADE given. Otherwise, we performed GRADE assessments. All evidence was observational, and was therefore given a default GRADE of 'low' certainty. GRADE certainties were downgraded if the evidence had high risk of bias, imprecision, inconsistency or indirectness. Certainties were upgraded if there was a large magnitude of effect, or if there was a dose response gradient.[15 16]

Deviation from protocol

Due to resource limitations, we excluded SRs not written in English in the final version of the review. We also included a

fourth question in the final version of the overview not present in the protocol: what are the effects of COVID-19 mitigation strategies, implemented in schools, on transmission, morbidity or mortality? This was an important question to add, to enable us to weigh the positive impacts of mitigations in schools (on transmission) against potential negative impacts (eg, on pupils' learning or mental health). In the manuscript, we added more detail to the review questions from the protocol. This increased the clarity of the review questions, and did not change their focus.

Patient and public involvement
Patients and the public were not involved in the planning or completion of the project.

Results

Results of search strategy
Figure 1 shows the PRISMA flow diagram for our overview. The search was performed on 20 February 2022, and was updated on 29 July 2022. A total of 578 records were identified: 145 from PubMed, 217 from Embase, 80 from Google Scholar, 9 from Cochrane Library, 115 from Epistemonikos and 12 from COVID-END. A total of 242 of these records were excluded as duplicates. The remaining 336 records were screened, and 267 were excluded after reading titles or abstracts. The full texts of 69 articles were screened, and 43 were excluded (23 because they did not answer any of our 4 posed questions—see the Methods section, 16 because they are not SRs, and 4 because they are not written in English—3 are in Italian and 1 in German) (figure 1). No further studies were added after searching included SRs' references, because none fit the inclusion criteria.

This gave rise to 26 SRs to include in the review: 11 SRs assessing the impact of COVID-19 school closures on transmission, morbidity or mortality, 14 SRs assessing the impact of COVID-19 school closures on children, 3 SRs assessing the impact of COVID-19 in-school mitigations on transmission, morbidity or mortality, and 0 SRs assessing the impact of COVID-19 in-school mitigations on children. Online supplemental table 1 lists the main characteristics of the included studies. Online supplemental table 2 lists the 310 reports identified by our search strategy but excluded from the synthesis.

Quality assessment of included SRs
We used the AMSTAR 2 quality appraisal method[14] to assess confidence in the included SRs. We assessed one of the included SRs to be high confidence, 0 medium, 10 low and 15 critically low confidence (table 1). SR quality was downgraded for a number of reasons. Fifteen SRs did not register a protocol, 4 did not perform screening in duplicate, 7 did not perform data extraction in duplicate, 23 did not list excluded studies, 2 did not include a full description of included studies, 5 did not assess risk of bias, 25 did not list the funding sources of included primary studies, 9 did not consider risk of bias in interpretation, 2 did not explain heterogeneity and 3 did not declare conflicts of interest (table 1).

Overlap
The relevant primary studies included in each SR, and their overlap, are shown in online supplemental table 3. The average number of unique primary studies in each group of SRs was as follows: 66% (range: 25%–100%, n=11 SRs) for school closures and COVID-19 transmission/morbidity/mortality, 89% (range: 69%–100%, n=4 SRs) for school closures and learning, 48% (range: 0%–89%, n=8 SRs) for school closures and mental health,

85% (range: 67%–100%, n=3 SRs) for school closures and physical health. 42% (range: 0%–67%, n=3 SRs) for school closures and sleep, 74% (range: 67%–80%, n=2 SRs) for school closures and domestic violence, and 100% (range: 100%–100%, n=3 SRs) for in-school mitigations and COVID-19 transmission/morbidity/mortality (online supplemental table 3). SRs with a higher proportion of unique primary studies were prioritised when synthesising results.

What is the impact of school closures on COVID-19 transmission, morbidity or mortality of people in the community?
Eleven SRs addressed the impact of school closures on COVID-19 transmission, morbidity or mortality.[17–27] Six SRs reported a reduction in transmission on school closures,[20–23 25 27] two SRs reported an uncertain effect on transmission of school closures[18 19] and two SRs reported no effect on transmission of school reopenings.[17 18] One SR reported a reduction in hospitalisations on school closures,[26] and one reported a reduction in mortality on school closures.[24] One SR reported the GRADE certainty for reduced transmission on school closures to be low,[23] one for no effect on transmission of re-opening schools to be low[17] and one for reduced hospitalisation on school closures to be low[26] (table 2).

Low-quality SRs
Chaabane *et al* (Unique primary studies: 100%) reported that school closures may have reduced paediatric hospitalisations.[26] Nussbaumer-Streit *et al*'s SR (Unique: 67%) reported that adding school closures onto other measures, such as mandatory quarantine for infected students, may have reduced transmission over quarantine alone.[23] Walsh *et al* (Unique: 64%) reported uncertain findings on school closures: half of the included primary studies at lower risk of bias found reduced community COVID-19 transmission on closing schools, while the other half reported that school closures were associated with no change in transmission. This SR further reported that school reopening was mostly not associated with increased community transmission, when community transmission was low and in-school mitigations were in place.[18]

Talic *et al* (Unique: 60%) reported that school closures were largely effective. Primary studies included in this SR were inconsistent on the efficacy of school closures, although most supported reduced community COVID-19 transmission on school closure.[21] Ayouni *et al*'s SR (Unique: 50%) reported that school closures were associated with reduced community transmission, but also that the specific effects of school closures were difficult to disaggregate, given the other NPIs introduced at the same time.[20]

Critically low-quality SRs
The National Collaborating Centre for Methods and Tools (NCCMT) (Unique: 82%) reported little evidence that reopening schools increased transmission when mitigations, such as mask-usage, were in place.[17] Caini *et al* (Unique: 87%) found that children may be less likely to transmit COVID-19 than adults, leading to limited transmission in schools.[19] In meta-analyses of observational studies, Caini *et al* reported that onward transmission from school pupils was less likely than from adults (OR 0.26, 95% CI (0.11 to 0.63)) and school pupils may be less likely to be infected with COVID-19 (OR 0.60, 95% CI (0.25 to 1.47)).[19]

Viner *et al*[24] (Unique: 67%) is an SR from very early in the pandemic (the latest search was 19 March 2020), but predicted—from primary modelling studies—a very small beneficial effect of school closures on community COVID-19 mortality.[24] The Muhammed SR reported that school closures may have been effective in reducing COVID-19 transmission (Unique: 63%).

Effectiveness appeared to be dependent on infection levels in the community, and the time that closures were introduced: earlier interventions, when community levels remained relatively low, were reported to be more effective.[22]

Mendez-Brito *et al*'s SR (Unique: 60%) concluded that school closures may be the most effective NPI, and were more effective when introduced earlier: 58% of included primary studies reported reduced transmission on school closure.[25] Finally, Suk *et al* included few unique studies (Unique: 25%), but reported that school children were rarely the index case for subsequent household transmission. Nevertheless, this SR reported that school closures may have reduced COVID-19 transmission.[27]

Taken together, the evidence suggests that school closures may have reduced community COVID-19 transmission, morbidity and mortality. A limitation of these data is that only one of the SRs performed quantitative meta-analysis. In most of the SRs, most of the included primary studies were unique (online supplemental table 3). The quality of the evidence was variable, with all studies of low or critically low quality (table 1), although exclusion of the SRs with critically low quality does not change the overall conclusion. The GRADE certainty for the evidence in transmission, morbidity and mortality is all very low (table 2).

What is the impact of school closures on pupils' learning and achievement?

Four SRs assessed the impact of school closures on pupils' learning and achievement.[26 28–30] Four SRs reported a decline in learning and achievement associated with school closures.[26 28–30] One SR assessed the certainty of the evidence by GRADE, which was reported as low[26] (table 2).

Low-quality SRs
Chaabane *et al* (Unique: 100%) reported that students from lower socioeconomic backgrounds, and those with disabilities, may have fared worse with online learning, due to reduced access to the internet and technology at home.[26] Bond *et al*'s SR (Unique: 96%) reported that some students were less engaged, and attendance was reduced, for virtual teaching at home—potentially due to social isolation. Furthermore, it appeared that some pupils lacked the technical skills required for the virtual learning to be effective.[30]

Critically low-quality SRs
Hammerstein *et al* (Unique: 91%) found loss of learning on closing schools, particularly affecting younger pupils and pupils from low socioeconomic backgrounds. The estimated learning loss was in the range of −0.005 to −0.05 SD per week of closures.[28] Similarly, Panagouli *et al* (Unique: 69%) reported that loss of learning on school closures was more severe in younger pupils and pupils with special educational needs (SEN). However, the SR also reported evidence that some students appeared to gain more from virtual learning than classical classroom teaching.[29]

Together, these SRs suggest that learning loss occurred during school closures, and SEN students, as well as those from lower socioeconomic backgrounds, appeared to be most affected. It appears that some students engaged less with virtual teaching methods than in-person methods, and virtual teaching may have exacerbated inequalities. There was minimal overlap between primary studies included in the SRs (online supplemental table 3), but the studies were of low or critically low quality (table 1), and the GRADE certainty for this evidence base is low (table 2).

What is the impact of school closures on pupils' mental health?

Eight SRs assessed the impact of school closures on pupils' mental health.[26 31–37] Eight SRs reported a decline in mental health associated with school closures.[26 31–37] One SR assessed the certainty of evidence using GRADE, which reported the evidence as low certainty[26] (table 2).

Low-quality SRs
Chaabane *et al* (Unique: 25%) reported increased anxiety and loneliness among students during school closures.[26] Samji *et al* (Unique: 89%) reported that female students were worse affected, as well as older students and pupils with neurodiversity. Nevertheless, effects on mental health could be mitigated, including if students exercised more at home or had better social support networks.[34]

Viner *et al*[35] (Unique: 60%) reported increased anxiety and reduced well-being during school closures, but no change in suicide rate.[35] Chai *et al* performed a meta-analysis of cross-sectional studies (Unique: 42%), reporting that 28% (95% CI (22% to 34%)) of Chinese students experienced mental health problems during school closures for COVID-19 – compared with best estimates (in a different population) of 17.6% (95% CI (17.4% to 17.9%)) before the pandemic.[37 38] Meherali *et al* (Unique: 23%) reported worse effects on mental health among female students, as well as among those who spent more time on social media—usage of which also appeared to increase during school closures.[33]

Critically low-quality SRs
Lehmann *et al* (Unique: 80%) reported worsening behaviour and hyperactivity among students, and noted that students' mental health during school closures became worse if their parents were suffering from stress. Lehmann *et al* caveat that unequivocal conclusions were difficult to draw, since multiple NPIs were often introduced simultaneously.[36]

Zhang *et al*'s meta-analysis of cross-sectional studies (Unique: 64%) reported that the prevalence of anxiety among Chinese students during the COVID-19 pandemic was 24% (95% CI (20% to 29%)). In subgroup analyses, Zhang *et al* reported that anxiety appeared to be worse in the diffusion attenuation phase of the pandemic (42%, 95% CI (35% to 50%)) than in the outbreak phase (25%, 95% CI (17% to 34%)).[31] Although they did not include any primary studies unique from the above SRs, Elharake *et al* (Unique: 0%) also reported a decline in mental health during school closures, and reported that risk factors for this included low socioeconomic status, and having family members who work in healthcare.[32]

Overall, these SRs suggest that COVID-19 school closures may have increased the prevalence of mental health problems—most notably anxiety—among children. A limitation of these data is that school closures were not applied as a solitary restriction; some effects on mental health may therefore also be effects of other restrictions, or from the wider context of the COVID-19 pandemic. There was moderate overlap between primary studies, and one SR (Elharake *et al*) presented zero unique primary studies (online supplemental table 3). The studies were of low or critically low quality (table 1), and the GRADE certainty for this evidence base is very low (table 2).

What is the impact of school closures on pupils' physical health?

Three SRs assessed the impact of school closures on pupils' physical health.[26 35 39] Three SRs reported a decline in physical health associated with school closures.[26 35 39] One SR assessed the certainty of evidence using GRADE, which reported low certainty in the evidence[26] (table 2).

Low-quality SRs

Chaabane *et al* (Unique: 67%) reported that school closures were associated with an increase in body mass index (BMI) and obesity, with predictions showing that longer closures would be associated with larger increases.[26] Similarly, Viner *et al*[35] (Unique: 88%) reported that school closures were associated with weight gain in children, as well as with reduced exercise, increased sedentary behaviour and increased unhealthy food consumption.[35]

Critically low-quality SRs

Chang *et al*'s meta-analysis of non-randomised studies (Unique: 100%) reported that the average BMI of pupils increased by 0.77 points (95% CI (0.33 to 1.20) p=0.0006), rates of obesity increased by 1.23-fold (95% CI (1.10 to 1.37) p=0.0002), and the average increase in bodyweight was 2.67 kg (95% CI (2.12 to 3.23) p<0.00001) (noted by the authors to be a greater increase than normal average growth), following COVID-19 lockdowns.[39]

Overall, these SRs suggest that school closures may have increased BMI and obesity among pupils—potentially due to reduced exercise coupled with a less healthy diet at home, where students did not have access to physical education teaching or healthy school meals. Given that school closures were not applied on their own, these changes may also reflect the wider context of the pandemic. There was little overlap between primary studies (online supplemental table 3), but the SRs were of low or critically low quality (table 1), and the GRADE certainty for this evidence base is very low (table 2).

What is the impact of school closures on pupils' sleep?

Three SRs assessed the impact of school closures on pupils' sleep.[26 35 40] Two SRs reported a decline in sleep quality associated with school closures,[35 40] and one SR reported no change to sleep quality associated with school closures[26] (table 2).

Low-quality SRs

Most of the 10 primary sleep studies included in the Viner *et al*[35] SR (Unique: 60%) reported reduced sleep quality during school closures, with many students developing new sleep problems and fewer students sleeping through the night.[35] Although they only included one primary study on sleep, which was not unique, Chaabane *et al* (Unique: 0%) concluded that sleep timing (but not sleep quality) was affected during school closures.[26]

Critically low-quality SRs

Sharma *et al* (Unique: 67%) conducted a synthesis of nine primary studies and reported that, in general, students slept later and woke later during school closures. They also reported that some students had better sleep quality during school closures, but three-times this number experienced a decline in sleep quality.[40] Meta-analysis found that 54% of pupils (95% CI (50% to 57%)) had sleep disturbance, and 49% (95% CI (39% to 58%)) did not achieve recommended sleep quantities during the pandemic.[40]

Although the quality of the SRs and their findings varied, there appears to be a trend to suggest that sleep quality reduced during school closures. This may be due to a mixture of increased anxiety and reduced physical activity. Nevertheless, there was some evidence that a subgroup of students reverted to a more natural sleeping routine, with many sleeping later and waking later. These changes could reflect school closures directly, but cannot be separated from the potential wider context of the COVID-19 pandemic. There was moderate overlap between primary studies, and one SR (Chaabane *et al*) presented zero unique primary studies (online supplemental table 3). The SRs were of low or critically low quality (table 1), and the GRADE certainty for this evidence base is very low (table 2).

What is the impact of school closures on domestic violence against children?

Two SRs assessed the impact of school closures on domestic violence against children.[35 41] One SR reported a possible increase in domestic violence associated with school closures,[41] and one SR reported an uncertain effect of school closures on domestic violence[35] (table 2).

Low-quality SRs

Viner *et al*[35] (Unique: 67%) described a consistent reduction in reports of child abuse during school closures, although no findings on incidence of abuse.[35]

Critically low SRs

Kourti *et al* (Unique: 80%) described that, around the world, reported cases of domestic violence against children reduced during school closures. Despite this, some studies suggested increased incidence of abuse, including increased numbers of children presenting to healthcare centres with abusive head trauma. Kourti *et al* suggested that this may be due to co-quarantine of perpetrators and victims.[41]

Together, these SRs suggest that reported cases of domestic violence may have reduced during school closures, but actual cases may have increased. There was little overlap between the primary studies in the SRs (online supplemental table 3). However, the studies were of low or critically low quality (table 1), and the GRADE certainty for the evidence base is very low (table 2).

What is the impact of in-school mitigations on COVID-19, transmission, morbidity and mortality?

Three SRs addressed the effects of in-school mitigations on COVID-19 transmission, morbidity or mortality.[17 42 43] Three SRs reported that in-school mitigations were associated with reduced transmission,[17 42 43] one SR reported an association with reduced hospitalisations,[42] and one SR reported an association with reduced mortality[42] (table 2). One SR reported the GRADE certainty for reduction in transmission as low,[17] and another reported the GRADE certainty for the reduction in transmission, morbidity and mortality as very low.[42]

High-quality SRs

Krishnaratne *et al* (Unique: 100%) reported that in-school mitigations, such as mask-wearing and isolation of positive cases, appeared to be effective in reducing community COVID-19 transmission, hospitalisation and mortality.[42]

Critically low-quality SRs

The NCCMT (Unique: 100%) found that mask-usage, social distancing, restricting school entrance to non-staff/non-students, stopping extracurricular activities, teaching outdoors and screening for symptoms of COVID-19, all appeared to reduce transmission in schools.[17] Vardavas *et al* (Unique: 100%) also reported that the mitigations introduced in schools appeared effective in reducing transmission, with little transmission occurring in schools when these measures were in place.[43]

Overall, these SRs suggest that the mitigations implemented in schools, such as mask usage, may be effective in reducing school and community transmission of COVID-19. There was no overlap between the primary studies included in the SRs (online supplemental table 3). One SR was high quality, but the others were of critically low quality (table 1); the conclusions of the high-quality study (Krishnaratne *et al*) were consistent with those of the other studies. The GRADE certainties for this evidence base—for the effect of in-school mitigations on transmission, morbidity and mortality—are all very low (table 2).

What is the impact of in-school mitigations during COVID-19 on children?

We found no SRs that addressed our fourth question: the effect of in-school mitigations on children (eg, on learning, physical or mental health).

Discussion

We performed an overview of 26 SRs to assess the positive and negative impacts of school closures, and in-school mitigations, during COVID-19. We found evidence that both school closures and in-school mitigations may have had a beneficial impact on reducing COVID-19 transmission in the community. However, the GRADE certainty was very low in both outcomes. We also found that school closures may have had negative impacts on children, including reduced learning, increased anxiety and increased rates of obesity. However, GRADE certainties were low or very low in these outcomes (table 2). Overall, confidence in the included SRs was generally low or critically low (table 1).

We observed some heterogeneity across the evidence base, particularly related to the impact of school closures on community transmission. A likely source of heterogeneity is that studies were performed in different countries, at different times of the pandemic, with different SARS-CoV-2 variants and different vaccination coverage (online supplemental table 1). Exclusion of the SRs with critically low quality does not change our overall conclusion that school closures were associated with reduced community COVID-19 transmission, suggesting that SR quality does not account for the heterogeneity.

There have not been any randomised controlled trials that have assessed the impact of school closures on COVID-19 transmission, which also likely contributes to the heterogeneity. For this reason, it is difficult to disaggregate the specific effect of each intervention, when multiple NPIs were introduced simultaneously. This also contributes to the low and very low GRADE certainties across individual outcomes, and means that recommendations to policy makers should be made with caution. Similarly, the quality of included SRs, measured by the AMSTAR 2 tool,[14] is generally low or critically low, highlighting the need for high-quality SRs in the future.

A recent study looked to address the lack of randomised studies using a retrospective approach, by matching the closed and open schools that were most similar in terms of potential confounding factors. This study, based in Japan, found that school closures were not associated with reduced community transmission of COVID-19.[44]

A main reason to close schools is to protect the family of school children from household COVID-19 transmission. However, none of the included SRs accounted for household size or number of vulnerable family members when assessing the efficacy of school closures on morbidity and mortality in the community. This is a limitation of our study, and should be addressed moving forward.

Another limitation of our study is that none of the SRs we have reviewed feature the currently dominant Omicron subvariants. This could reduce the applicability of our study's findings with respect to the ongoing evolution of the pandemic, although it should be noted that the recent Omicron waves caused fewer deaths than previous waves.[45] Similarly, the original COVID-19 vaccines have retained their protection against severe disease from Omicron,[46] and vaccination considerably reduced COVID-19 fatality rates during Omicron waves.[47] Moving forward, this protection is increased further by a bivalent booster dose containing Omicron's Spike mRNA, which is now being used in booster programmes across the world.[48] Despite increased transmission of Omicron versus previous variants, including in schools,[49] the continued vaccination of children,[50] which was not widespread in previous waves, may compensate for the transmission advantage of Omicron.

Although we have reviewed a lack of Omicron data, a recent study, which looked at the efficacy of mask usage in schools during Omicron waves, found evidence consistent with our conclusions. This study assessed the effects of removing school mask rules in the US during February–June 2022, when Omicron variants were dominant.[51] The study found that removal of mask rules in schools was associated with 44.9 extra COVID-19 cases per thousand students and staff (95% CI (32.6 to 57.1)), representing 29.4% of all COVID-19 cases during the study period, and highlighting the efficacy of masks in schools, including against Omicron.[51]

Although we were able to analyse most of our planned outcomes, we found no SRs that assessed the effect of in-school mitigations—such as masks and social distancing—on children's health and well-being. Given the importance of considering an intervention's negatives alongside its positives, this is an area that should receive additional research attention in the future.

A final limitation is that we were unable to perform quantitative meta-analysis due to a lack of amenable data, so we were limited to narrative synthesis.

In conclusion, our findings suggest that the benefits of school closures in reducing community transmission of COVID-19 should be considered in the context of the harms on children's education, health and well-being. This overview may inform future planning for school closures during pandemic outbreaks.

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