Philippine COVID-19 Living Clinical Practice Guidelines
Institute of Clinical Epidemiology, National Institutes of Health, UP Manila
In cooperation with the Philippine Society for Microbiology and Infectious Diseases
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EVIDENCE SUMMARY

RESEARCH QUESTION: In the community, should carbon dioxide (CO2) monitors can be used to reduce transmission of COVID-19?

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RECOMMENDATIONS

Recommendations	Certainty of Evidence	Strength of Recommendation
We suggest the use of carbon dioxide (CO2) monitors in enclosed spaces to guide actions to improve ventilation and reduce the risk of transmission of SARS-CoV-2.	Low	Weak

Consensus Issues
Panel members clarified the appropriateness and completeness of the evidence question “Should Carbon Dioxide monitors be used to reduce the transmission of COVID-19?”. It was clarified that the question precludes an intermediary outcome that is not explicitly stated (for example, using CO2 monitors to improve ventilation). The Steering Committee clarified that the more important outcome is clinical in nature, that is: reducing transmission of COVID-19, of which the results were based on mostly indirect evidence.

KEY FINDINGS

- In this update, we found no studies that directly answered the research question; hence, the studies presented constitute indirect evidence.
- Mathematical modelling described that the air renewal rate has a significant role for event durations >0.5hr and that transmission probability decreased with opened windows.
- The estimated transmission risk (Hr) for COVID-19 ranged from intermediate (with surgical masks) to high (no masks, teacher infected). Controlled mechanical ventilation systems and wearing well-fitting FFP2–N95 masks indoors contributed to the decrease transmission risk of COVID-19 (AR 35%/50%, without masks for Alpha and Omicron BA.1 to 20%/30% with mask).
- The fraction of rebreathed air can be inferred from the ratio of CO2 concentration in the room and the estimate of the fraction of infected air is translated into a likelihood of infection rate.
- The higher the number of visitors in an area, the higher the predicted CO2 concentration.
- In a clinical cardiology clinic setting, aerosol concentration increased with increasing CO2 levels and in a well-ventilated room, the aerosol concentration and CO2 levels declined after the stress test stopped.
- An RCT revealed that the median time per day with CO2 concentration >800 ppm was 110 minutes prior to the use of CO2 monitors, 82min in the sham control (CO2 monitors face down) and 78min in the intervention (with CO2 monitor readings shown).

- Perceived actions to reduce CO_2 levels include opening windows and doors, taking periodic breaks where occupants can leave the room, reducing occupancy and avoiding high intensity activities, increasing fresh air supply, keeping ventilation fans running during occupied periods, and installing local exhaust systems.

WHAT'S NEW IN THIS VERSION?

- Eight new studies were added to the initial 6 studies in the previous evidence summary.
- New evidence is comprised of 2 observational studies, 1 cross-sectional study, 2 data modelling, 1 RCT, and 2 case studies. Three observational studies described ventilation as a function of CO2 concentration (Vernez et. al, Huessler et al, and Somsen et. al).
- One study (Burridge et. al) used mathematical modelling to estimate the baseline probability of airborne infection using CO2 level as variable.
- One cross-sectional study (Rodriguez et al), used CO2 levels in estimating COVID-19 infection risk while another study (Costanzo et. al) integrated the estimation of risk levels in a mobile application.
- One randomized controlled trial measured the length of time that carbon dioxide levels exceeded 800ppm, 1000ppm, and 1400ppm before, during, and after the use of carbon dioxide monitors.
- Two studies demonstrated possible limitations and harm in using CO2 monitors in estimating COVID-19 risk of infection.
- Lastly, one case study discussed that provision of theoretical basis and guidance resulted in better understanding of ventilation system and airborne transmission risk using CO2 monitors.
- Additional recommendation from the Welsh government on the use of CO2 monitors.

PREVIOUS RECOMMENDATIONS
As of 05 November 2021

We recommend the use of carbon dioxide (CO2) monitors in enclosed spaces to guide actions to improve ventilation and reduce transmission of SARS-CoV-2. *(Moderate certainty of evidence; Strong recommendation)*

Consensus Issues
The panel made a strong recommendation for the use of carbon dioxide (CO2) monitors because of the moderate certainty of evidence based on an indirect study that showed much higher risk of contracting tuberculosis when exposed to a room whose air reached 1000 parts per million (ppm) of carbon dioxide. The panel believed CO2 monitors could serve as a real-time guide to initiate activities that improve air ventilation (such as promoting distancing, opening windows, or turning on electric fans). However, two panelists still voted for a weak recommendation due to (1) unknown accuracy of various commercial monitors in detecting CO2 levels and (2) concerns regarding the actual use of industrial-grade monitors (training of personnel, number of monitors needed, calibration, preventive maintenance) in different institutions. Even with the use of CO2 monitors, the public must continue to observe the precautionary measures of handwashing, wearing face masks, and observing physical distancing to avoid infection with COVID-19.

INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic accounts for 6.5M deaths globally as of December 2022 [1] and every day, new cases are being reported. One of the mechanisms of spread of the SARS-CoV-2 virus is via aerosols [2,3]. Airborne transmission occurs when there is spread of infectious droplet nuclei or 'aerosols' that are suspended in air for long period and distance [Rudnick]. Carbon dioxide level has been used to estimate the risk of indoor airborne infection through indoor scenarios and application of the Wells-Riley mathematical modeling [4].

Three studies directly measured the virus in exhaled breaths or air samples within the vicinity of the COVID-19 patient. Ma et al (2020) demonstrated that the highest virus content was in exhaled breath condensate (EBC) (14/52, 26.9%) followed by surface swabs and air samples [5]. The study of Lednicky et. al (2020) showed viable SARS-CoV-2 virus isolated from air samples collected 2-4.8m away from COVID-19 patients [6]. Cheng and colleagues (2020) collected air samples in airborne infected isolation rooms (AIIR) of COVID-19 patients but the samples were negative for SARS-CoV-2 RNA [7]. However, environmental samples (bedrails, lockers, bed tables – area of 9cm^2) showed that cell phone and bed rail had the two highest concentrations of virus. This study supports that in an indoor setting, it is possible that exhaled viral particles may be present both in air samples and as fomites and can settle in environmental areas near the infected individual. Van Doremalen and colleagues showed that SARS-CoV-2 is stable in airborne particles with half-life of >1 hour making it potentially be inhaled in an enclosed space and cause infection [2].

There is accumulating evidence that indoor air quality is inversely associated with carbon dioxide levels, hence, CO2 levels are used as a surrogate measure for ventilation status and transmission risk of respiratory infections that are spread through droplet and aerosol mechanisms [4,8,9,10]. Despite robust correlations of CO2 levels with quality of ventilation and risk of air-borne infection transmission, direct evidence regarding the use of CO2 monitors to mitigate COVID-19 transmission is still lacking. In a review done by Eykelbosh and colleagues, it was recommended that in indoor settings, CO2 levels should not be interpreted as a proxy for COVID-19 risk [11]. There is no global consensus on the optimal indoor CO2 level cut-offs in the context of COVID-19 but regulatory bodies in various countries recommended to maintain indoor CO2 concentrations below 800-1000ppm [12,13].

Measures to mitigate the airborne spread of SARS-CoV-2 include sufficient ventilation provision but large-scale changes are costly and will take time. Heating, ventilating, and air conditioning (HVAC) systems are the usual means to provide ventilation in commercial establishments. These are complex systems that, when modified to reduce airborne transmission risk, entail engineers and additional costs [14]. COVID-19 airborne precautions set by the World Health Organization (WHO) in naturally ventilated rooms when performing aerosolizing procedures require at least 160L/s per patient air flow and at least 12 air changes in mechanically ventilated negative-pressure rooms [15].

Occupancy reduction is another practice that is more appealing. Reducing the occupancy by half by introducing week-in and week-out working schedule reduces secondary airborne infection by a factor of about four [16]. This translates to a theoretical reasoning that reducing occupancy by a factor of *r* reduces the number of secondary airborne by a factor of r^2.

Morawska et al advocated for the avoidance of air re-circulation to prevent dissemination of virus-laden particles indoors [14]. This can be achieved by operating on outdoor air and closing recirculation dampers [14].

REVIEW METHODS

We searched Pubmed, TRIP database, clinicaltrials.gov, Epistemonikos, medrxiv, Google Scholar, and Google to identify articles related to indoor CO2 monitoring and COVID-19 risk of infection. Public health guidance documents that used CO2 monitoring as a surrogate for infection risk were also sourced. Our search included the following PICO elements: P – individuals without COVID-19, at risk for COVID-19, healthcare workers, essential frontliners, household and occupational contacts, vaccinated individuals, general public; I – use of CO2 monitors/levels; C – non-use of CO2 monitors/levels; O – risk of COVID-19 infection, risk for respiratory diseases, indoor air quality. Our search also utilized Boolean operator combinations and synonyms like “rooms,” “enclosed spaces,” “indoor,” “CO2,” “carbon dioxide,” “air quality,” “COVID-19,” and “SARS CoV-2.”

We included , observational studies (cross-sectional, cohort), and experimental studies (e.g., before and after an intervention) to analyze how CO2 levels were used as surrogate for ventilation status and consequently as estimate for risk of airborne infection. We included study protocols to discuss limitations and risk of using CO2 monitors as well.

RESULTS

The initial review evaluated (1) the effects of CO2 level in risk of respiratory disease (pulmonary tuberculosis) or nosocomial infection, (2) relationship of air ventilation on CO2 concentration, (3) CO2 and aerosol concentration, (4) effects of CO2 level in sick building syndrome (SBS), and (5) possible harm/misinterpretation in the use of CO2 monitors.

The study of Du et al showed that individuals exposed to TB in a room with CO2 levels ≥1000ppm were 16 times more likely to acquire TB infection, compared to individuals in a room with CO2 level <1000ppm (RR 16.1, 95% CI 2.17-119.5) [15]. Since there is similarity in the mode of transmission of TB and SARS-CoV-2, the findings of Du et. al constitute indirect evidence that improving ventilation resulted to lower CO2 concentration and subsequently, lower transmission of a respiratory disease. The results of the study are summarized in the table below:

Table 1. Acquired TB infection and Room CO2 level (ppm)

Contact in CO2 level ≥ 1000ppm	Acquired TB (n=22)	Did not acquire TB (n=1643)	*P* value
NO	1 (4.5%)	722 (43.9%)	<0.0001
YES	21 (95.5%)	921 (6.1%)	

Di Gilio and colleagues investigated the occurrence of nosocomial COVID-19 in areas where ventilation rate and CO2 levels were measured [10]. No patient contracted nosocomial COVID-19 during their study period but they showed that the higher the ventilation rate in their study sites, the lower the CO2 levels.

In an experimental investigation by Schade and colleagues, they showed a direct positive linear correlation between CO2 concentration and aerosol concentration (r=0.77) (Figure 2) [16]. They used a simulated concert hall as a setting of an enclosed area, with aerosol generation done using a dummy infector with and without mask.

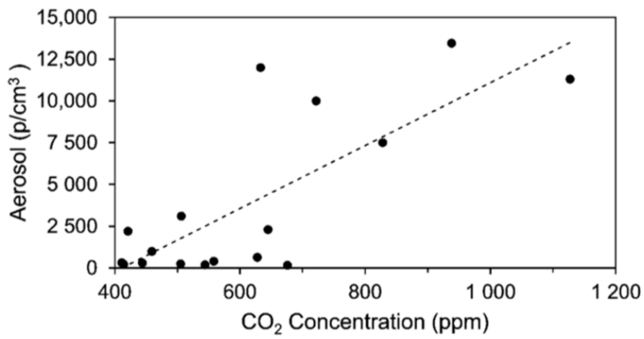

Figure 2. Relationship between aerosol and CO2 concentration

The study of Tsai and colleagues demonstrated that there are higher odds of developing signs of sick building syndrome (eye irritation and URTI) with higher CO2 concentrations in an office. Sick building syndrome (SBS) is defined as having symptoms that cannot be associated with a well-defined cause but that appear to be linked with time spent in a building [17]. Their study was cross-sectional including 111 office workers in an office floor. They measured the OR for each symptom and correlated them with CO2 concentration of <500ppm vs. >800ppm. They found that eye irritation had an OR=1.7 (95% CI 1.1-2.7; p=0.01) and URTI had an OR=1.7 (95% CI 1.0-2.7; p=0.03) [17].

In a separate study by Hou et. al where they administered a questionnaire every month for 11 months to a sample population of n=1285, they found that the AOR (adjusted odds ratio) of relative humidity for general (fatigue, heavy head, headache, dizziness, difficulty concentrating) and skin SBS (dry facial skin, dry ears, dry hands) were higher in areas with high CO2 concentrations than in those with low CO2 concentrations (OR=1.02, 95% CI 0.97-1.08 for general SBS; OR=1.03, 95% CI 0.99-1.08 for skin SBS) [18].

The original review also included the technical use of indoor CO2 sensors. They emphasized that its use in COVID-19 risk mitigation may result in misinterpretation and dependency [11]. The utility of CO2 sensors does not exclude the other factors such as the use of masks, room size, and occupant's activity in identifying risk for SARS-CoV-2 transmission. Approaches to reduce CO2 levels discussed in the original study include opening of windows and doors, taking periodic breaks for occupants, reduction of occupancy, keeping ventilation fans working, etc [11].

The studies included in this update described 1) the relationship of air ventilation and CO2 concentration with aerosol concentration, 2) estimation of risks and magnitude of secondary COVID-19 infection with CO2 levels, 3) the use of CO2 monitors as guide for improving ventilation, and 4) limitations and possible harm of using CO2 monitors as measure of ventilation.

Ventilation and CO2 Concentration as functions of aerosol spread

Vernez et al.'s field analysis of a courtroom hearing where COVID-19 clustering was noted revealed that SARS-CoV-2 infection was related to unfavorable indoor conditions of ventilation, emission rate, and event durations [19]. This study utilized Lactose aerosols as surrogate for measuring the spread of viral quanta. They found that aerosols aggregate after being emitted and thus have adsorptive capacity for viruses. The study revealed that higher emission rates and longer event duration were associated with increased probability of infection. Air renewal rate was measured using CO2 levels as function of time. Their mathematical model described that the air renewal rate has a significant role for event durations >0.5hr and that transmission probability decreased with opened windows [19].

An observational study done by Huessler et. al measured CO2 concentration in a fitness center to assess the justifiability of its reopening [20]. In this study, they found that the CO2 concentration of 400ppm for fresh air was exceeded most of the time but the threshold of 1000 ppm for medium quality air was never reached. This correlates with adequate ventilation as air change rate is proportional to ventilation rate. The number of visitors in the fitness center contributed to the predicted CO2 concentration such that 45 additional visitors predicted CO2 concentration to be 100 ppm larger, with the estimated effect of 2.24 ppm per person [20].

Somsen and colleagues investigated the risk of aerosol transmission of SARS-CoV-2 in a clinical cardiology setting. In their study, patients were subjected to cardiac exercise stress testing for work up. They found that the aerosol concentration increased with increasing CO2 levels [21]. Moreover, they found that in a well-ventilated room, the aerosol concentration and CO2 levels declined after the stress test stopped [21]. In the low ventilation setting, however, the aerosols persist and CO2 level remained high even at 5mins after the cessation of stress test.

Burridge and colleagues used mathematical modelling and demonstrated the estimation of baseline probability of airborne infection as a function of occupancy level and monitored CO2 levels. In a hypothetical regularly-attended space such as a moderately-sized open-plan office, doubling the outdoor ventilation rate per person decreases the likelihood of airborne infection by almost 50% [22].

Estimating risks and magnitude of secondary COVID-19 infection

The Wells-Riley model is a well-studied approach to estimating risk of airborne infection [16]. It states that the infectivity rate is directly proportional to the number of infected people in an area, the pulmonary ventilation rate, and the unit of infection via aerosols or 'quantum'. Conversely, the infectivity rate is inversely proportional to the ventilation rate of a space.

The work of Rudnick and Milton highlighted that airborne infection occurs through inhalation of rebreathed infected air [16]. It is important to note that the most dominant source of CO2 in an enclosed space is human emissions. Since direct measurement of infected aerosols in air is challenging and costly, monitoring of CO2-rich human gaseous emissions can be a practical approach to estimate the risk of transmission. Combining the principles of Wells-Riley and Rudnick-Milton, the fraction of rebreathed air can be inferred from the ratio of CO2 concentration in the room and the estimate of the fraction of infected air is translated into a likelihood of infection rate [4].

Application of the Wells-Riley model for disease propagation simulation was done in the study by Rodriguez et. al. They evaluated university and secondary school classrooms' ventilation conditions, relative transmission risk of SARS-CoV-2 (Alpha and Omicron BA.1), and indoor air quality (IAQ). Ventilation was assessed using outdoor and indoor CO2 levels and COVID-19 infection risk was measured using a free online estimator COVID Risk^{Airborne} (https://www.covidairbornerisk.com/). They showed that despite IAQ inside the classrooms being good, the estimated transmission risk (Hr) for COVID-19 ranged from intermediate (with surgical masks) to high (no masks, teacher infected) [23]. Consequently, they found that controlled mechanical ventilation systems and wearing well-fitting FFP2–N95 masks indoors contributed to the decrease transmission risk of COVID-19 (AR 35%/50%, without masks for Alpha and Omicron BA.1 to 20%/30% with mask) [23].

Integration of the Wells-Riley probabilistic model in a mobile app was done in the study by Costanzo et. al. They showed that the application allowed for measurement of permanence time, maximum allowed number of people for the specified area, the expected number of COVID-19 cases, and the required number of air changes per hour in an area [24].

Carbon dioxide real-time field measurement and occupancy monitoring were utilized in the study by Tang et. al. They demonstrated that location is an important factor influencing the infection risk because of the non-uniform airflow and varying dilution effects of viral aerosols at each point of measurement, resulting in different virus concentrations [25]. Additionally, they reported that dwell time is an important factor for risk assessment and that the relation of length of exposure with risk of infection is non-linear.

Carbon dioxide monitors as guide for improving ventilation

A randomized cross-over trial investigating the effects of placing CO2 monitors on the length of time per day that CO2 levels reached >800ppm, >1000ppm, or >1400ppm was done by Laurent and colleagues [26]. Their study had a high occupancy rate at 95.2%. They reported that the baseline median time per day with CO2 concentration >800ppm was 110min (7.6% of the day; IQR 47–207min, p=01511 vs. intervention), 82min in the control/no CO2 monitors (5.7%, IQR 12–226.5min, P >0.99 vs. intervention), and 78min in the intervention period (5.4%, IQR 20–154min) [Laurent]. CO2 levels >1000ppm was noted for 2min at baseline (IQR 0–19, P =0.0064 vs. intervention) and 0min in both control (IQR 0–20, P =0.2366 vs. intervention) and intervention (IQR 0–2); while levels >1400ppm was noted only for 3min in one day in one room. The differences in the outcomes between control and intervention groups were not significant (P =0.77, P =0.052 and P =0.22, respectively), but were significant for intervention versus baseline. Barriers identified to improving and altering ventilation systems were 1) patients complaining from cold and draft discomfort from increased ventilation, 2) lack of attention drawn by the monitors, 3) nurses and other clinical staff having many other responsibilities resist alterations in their work [26].

Limitations and possible harm of using CO2 monitors as measure of ventilation

In the original review, it was discussed that the use of CO2 monitors may be 1) threshold-based, where one sets an appropriate action limit, or 2) trend-based, where a data logging feature is used to display the CO2 curve and an action is taken when the curve is going upward. Consequently, perceived actions to reduce CO2 levels may include 1) opening windows and doors 2) taking periodic breaks where occupants can leave the room 3) reducing occupancy and avoiding high intensity activities 4) increasing fresh air supply 5) keeping ventilation fans running during occupied periods, and 5) installing local exhaust systems. Eykelbosh and colleagues suggested that placement of CO2 monitors should be 0.5-2.0 meters above floor and should be avoided in the following: near windows, near 2m of any human contact and within 2m of open flame [11].

Corollary to the above findings, we surmise that indoor air quality measurement using CO2 levels poses a risk of inaccuracy in that there is variability of CO2 concentrations in an enclosed space. By virtue of gravitational settling, the non-uniformity of airflow in a room, and sensitivity of CO2 to occupancy rate, CO2 levels in a building may vary [27]. In a case study by Ackley and colleagues, they demonstrated that variability in CO2 levels is higher in occupied than unoccupied spaces [27]. This translates to unreliable predictions of CO2 concentration and airborne transmission risk using one-point sensors. Recommendation from Ackley and colleagues involves the use of more than one sensor to improve the accuracy of CO2 monitoring.

In the previous review we introduced the concept of technological dependence on CO2 monitors which occurs when the focus becomes the readout on the sensor rather than on promoting awareness of airborne transmission prevention such as wearing of masks, social distancing, etc. Misinterpretation may include a sense of complacency when CO2 level is low or below threshold. Despite the risks of use of CO2 monitors, Jensen and colleagues showed that provision of theoretical basis and guided use of the device in an undergraduate setting promoted better understanding of ventilation and filtration in the context of COVID-19 airborne transmission [28].

EVIDENCE TO DECISION

The price of a CO_2 sensor/monitor ranges in online shops from ₱865 – ₱4,501 [36]. While these are readily accessible and available to individual users in metropolitan areas with internet connection, the same cannot be said for all rural or geographically isolated and disadvantaged areas (GIDAs) unless funded and sourced by third parties.

RECOMMENDATIONS FROM OTHER GROUPS

Source	Document Type	Description	CO2 Action Limit
German Umweltbundesamt [29]	Guidance document	As of 2021, recommends fixed or portable CO2 “traffic lights” in schools to remind teachers and students to periodically open windows to facilitate classroom ventilation.	Lower green-yellow threshold set at 1000ppm; yellow- red threshold set at 2000ppm.
Minnesota Department of Health [30]	Guidance document	Recommends CO2 monitoring to assess ventilation adequacy in classrooms with high occupancy as of 2021	Keep rooms below 800ppm.
UK Scientific Advisory Group for Emergency [31]	Public health guidance document	Supports the notion of using CO2 monitors to identify poorly ventilated spaces and prioritize them for remediation as of 2020. Notes that low CO2 levels do not necessarily indicate sufficient ventilation in low-occupancy or high-volume spaces. Rejects the notion that CO2 can be used as a direct proxy of COVID-19 risk.	Spaces with CO2 levels >1500ppm should be prioritized for remediation. Spaces with aerosol- generating activities should aim for 800ppm CO2.
US Centers for Disease Control and Prevention [32]	Public health guidance document	Supports using portable CO2 sensors with a logging function to monitor indoor spaces as of 2021.	A portable air cleaner should be considered for spaces that cannot be maintained below 800ppm.

Washington State [33]	Public health guidance document	CO2 monitoring required to ensure that "open air" eating places (i.e., patios or restaurants with large open windows) are truly open to the outdoors as of 2021.	If seated occupants are exposed to >450 ppm for 15min, they must be moved to a better ventilated table.
Department of Labor and Employment (Philippines) [34]	Public Guidelines for workplaces and public transport to prevent and control the spread of Covid-19	CO2 monitoring (Section 6.B.2. Quantitative Assessment). CO2 level inside an enclosed space may be determined by using a calibrated CO2 monitoring device	CO2 shall not exceed 1,000ppm.
Welsh Government Llywodraeth Cymru [35]	COVID infection risk control and improving ventilation: Carbon Dioxide monitors in education settings	As of 2021, emphasized that CO2 monitors (Rototherm AM60) are indicator of ventilation status and not infection risk. Supports use of CO2 monitors in the ff places: teaching spaces, indoor play spaces, staff rooms, large offices, meeting rooms, group or breakout rooms	Less than 800 ppm: No action 800-1500 (occasionally): increase ventilation by opening windows 800-1500 (consistently): increase rate and extend timing of mechanical ventilation Above 1500: consult with estates or facilities management

ONGOING STUDIES AND RESEARCH GAPS

Although CO2 monitoring may indicate indoor air quality, there is still paucity of evidence regarding the relationship of CO2 levels and COVID-19 transmission risk. There are no studies that directly compare COVID-19 cases in a group using CO2 monitors versus no CO2 monitors. Direct studies looking into the role or benefit of using CO2 monitors to decrease COVID-19 cases are ne

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Appendix 1: Preliminary Evidence to Decision

Table 1. Summary of initial judgements prior to the panel discussion (N=5/9)

FACTORS	JUDGEMENT						RESEARCH EVIDENCE/ADDITIONAL CONSIDERATIONS
Problem	No	Yes (N=3)	Varies (N=2)	Uncertain			
Benefits	Large	Moderate (N=1)	Small (N=1)	Varies (N=2)	Uncertain (N=1)	Trivial	Mere use of CO2 monitors without proper ventilation strategies will not result in decrease of COVID-19 transmission risk
Harms	Large	Moderate	Small (N=3)	Uncertain	Varies (N=2)		No serious adverse events related to use of CO2 monitors was reported in all studies
Balance of Benefits and Harms	Favors the use of CO2 monitoring	Probably favors the use of CO2 monitoring (N=4)	Probably favors no CO2 monitoring (N=1)				
Certainty of Evidence	High	Moderate	Low (N=2)	Very low (N=3)			
Accuracy	Very Accurate	Accurate (N=1)	Inaccurate	Very Inaccurate	Varies (N=2)	Don’t Know (N=2)	

Values	Important uncertainty or variability	Possibly important uncertainty or variability (N=3)	Possibly NO important uncertainty or variability (N=2)	No important uncertainty or variability			
Resources Required	Varies (N=1)	Large cost (N=1)	Moderate Cost (N=2)	Negligible cost or savings (N=1)	Moderate savings	Large savings	The price of a CO2 sensor/monitor ranges in online shops from ₱865 – ₱4,501.[36] While these are readily accessible and available to individual users in metropolitan areas with internet connection, the same cannot be said for all rural or geographically isolated and disadvantaged areas (GIDAs) unless funded and sourced by third parties.
Certainty of evidence of required resources	No included studies (N=2)	Very low (N=1)	Low (N=1)	Moderate	High (N=1)		The price of a CO2 sensor/monitor ranges in online shops from ₱865 – ₱4,501[TT1] .[36] While these are readily accessible and available to individual users in metropolitan areas with internet connection, the same cannot be said for all rural or geographically isolated and disadvantaged areas (GIDAs) unless funded and sourced by third parties
Cost effectiveness	No included studies (N=1)	Favors the comparator (N=1)	Does not favor either CO2 monitoring or the comparator (N=1)	Probably favors the CO2 monitoring (N=1)	Favors self-test	Varies (N=1)	
Equity	Don't Know	Reduced	Probably no impact (N=2)	Probably Increased (N=1)	Increased	Varies (N=2)	
Acceptability	Don't Know	No	Probably No (N=1)	Yes	Probably yes (N=2)	Varies (N=2)	
Feasibility	Don't Know	No	Probably No	Yes (N=1)	Probably yes (N=4)	Varies	

Appendix 2: Search Yield and Results

Search nu	Query	Sort By	Filters	Search Details	Results	Time
13	#7 AND #12 AND #11			("covid 19"[All Fields] OR "covid 19"[MeSH Terms] OR "covid 19 vaccines"[All Fields] OR "covid 19 vaccines"[MeSH Terms] OR "covid 19 serotherapy"[All Fields] OR "covid 19 serothera	38	04:54:43
12	#8 OR #9			"CO2"[All Fields] OR ("carbon dioxide"[MeSH Terms] OR ("carbon"[All Fields] AND "dioxide"[All Fields]) OR "carbon dioxide"[All Fields]) OR (("CO2"[All Fields] AND ("level"[All Fields] OR	219,516	04:54:14
11	(indoor space) OR (closed space) OR (Closed ventilation)			(("indoor"[All Fields] OR "indoors"[All Fields]) AND ("space"[All Fields] OR "space s"[All Fields] OR "spaces"[All Fields])) OR (("close"[All Fields] OR "closed"[All Fields] OR "closely"[All Fie	36,939	04:50:34
10	#8 OR #7			"CO2"[All Fields] OR ("carbon dioxide"[MeSH Terms] OR ("carbon"[All Fields] AND "dioxide"[All Fields]) OR "carbon dioxide"[All Fields]) OR ("covid 19"[All Fields] OR "covid 19"[MeSH Te	537,750	04:47:19
9	(CO2 level) OR (Carbon dioxide level)			("CO2"[All Fields] AND ("level"[All Fields] OR "levels"[All Fields])) OR (("carbon dioxide"[MeSH Terms] OR ("carbon"[All Fields] AND "dioxide"[All Fields]) OR "carbon dioxide"[All Fields]) A	37,258	04:47:04
8	(CO2) OR (Carbon dioxide)			"CO2"[All Fields] OR ("carbon dioxide"[MeSH Terms] OR ("carbon"[All Fields] AND "dioxide"[All Fields]) OR "carbon dioxide"[All Fields])	219,516	04:46:45
7	(((COVID-19) OR (SARS-CoV-2)) OR ((COVID infection)) OR (COVID)			"covid 19"[All Fields] OR "covid 19"[MeSH Terms] OR "covid 19 vaccines"[All Fields] OR "covid 19 vaccines"[MeSH Terms] OR "covid 19 serotherapy"[All Fields] OR "covid 19 serothera	319,074	04:46:12
6	#2 AND #3			("crowd s"[All Fields] OR "crowding"[MeSH Terms] OR "crowding"[All Fields] OR "crowd"[All Fields] OR "crowded"[All Fields] OR "crowds"[All Fields]) AND ("carbon dioxide"[MeSH Term	62	04:37:46
5	#2 OR #3			"crowd s"[All Fields] OR "crowding"[MeSH Terms] OR "crowding"[All Fields] OR "crowd"[All Fields] OR "crowded"[All Fields] OR "crowds"[All Fields] OR ("carbon dioxide"[MeSH Terms]	161,869	04:37:22
4	indoor air			"indoor air"[Journal] OR "indoor air int conf indoor air qual clim"[Journal] OR ("indoor"[All Fields] AND "air"[All Fields]) OR "indoor air"[All Fields]	23,293	04:36:17
3	carbon dioxide			"carbon dioxide"[MeSH Terms] OR ("carbon"[All Fields] AND "dioxide"[All Fields]) OR "carbon dioxide"[All Fields]	137,768	04:36:11
2	crowding			"crowd s"[All Fields] OR "crowding"[MeSH Terms] OR "crowding"[All Fields] OR "crowd"[All Fields] OR "crowded"[All Fields] OR "crowds"[All Fields]	24,163	04:35:49
1	SARS-CoV-2			"sars cov 2"[MeSH Terms] OR "sars cov 2"[All Fields] OR "sars cov 2"[All Fields]	185,288	04:35:42

Information source	Search strategy	Yield:	Eligible:
MEDLINE (Pubmed)	("covid 19"[All Fields] OR "covid 19"[MeSH Terms] OR "covid 19 vaccines"[All Fields] OR "covid 19 vaccines"[MeSH Terms] OR "covid 19 serotherapy"[All Fields] OR "covid 19 serotherapy"[Supplementary Concept] OR "covid 19 nucleic acid testing"[All Fields] OR "covid 19 nucleic acid testing"[MeSH Terms] OR "covid 19 serological testing"[All Fields] OR "covid 19 serological testing"[MeSH Terms] OR "covid 19 testing"[All Fields] OR "covid 19 testing"[MeSH Terms] OR "sars cov 2"[All Fields] OR "sars cov 2"[MeSH Terms] OR "severe acute respiratory syndrome coronavirus 2"[All Fields] OR "ncov"[All Fields] OR "2019 ncov"[All Fields] OR (("coronavirus"[MeSH Terms] OR "coronavirus"[All Fields] OR "cov"[All Fields]) AND 2019/11/01:3000/12/31[Date - Publication]) OR ("sars cov 2"[MeSH Terms] OR "sars cov 2"[All Fields] OR "sars cov 2"[All Fields]) OR (("sars cov 2"[MeSH Terms] OR "sars cov 2"[All Fields] OR "covid"[All Fields] OR "covid 19"[MeSH Terms] OR "covid 19"[All Fields]) AND ("infect"[All Fields] OR "infectability"[All Fields] OR "infectable"[All Fields] OR "infectant"[All Fields] OR "infectants"[All Fields] OR "infected"[All Fields] OR "infecteds"[All Fields] OR "infectibility"[All Fields] OR "infectible"[All Fields] OR "infecting"[All Fields] OR "infection s"[All Fields] OR "infections"[MeSH Terms] OR "infections"[All Fields] OR "infection"[All Fields] OR "infective"[All Fields] OR "infectiveness"[All Fields] OR "infectives"[All Fields] OR "infectivities"[All Fields] OR "infects"[All Fields] OR "pathogenicity"[MeSH Subheading] OR "pathogenicity"[All Fields] OR "infectivity"[All Fields])) OR ("sars cov 2"[MeSH Terms] OR "sars cov 2"[All Fields] OR "covid"[All Fields] OR "covid 19"[MeSH Terms] OR "covid 19"[All Fields])) AND ("CO2"[All Fields] OR ("carbon dioxide"[MeSH Terms] OR ("carbon"[All Fields] AND "dioxide"[All Fields]) OR "carbon dioxide"[All Fields]) OR (("CO2"[All Fields] AND ("level"[All Fields] OR "levels"[All Fields])) OR (("carbon dioxide"[MeSH Terms] OR ("carbon"[All Fields] AND "dioxide"[All Fields]) OR "carbon dioxide"[All Fields]) AND ("level"[All Fields] OR "levels"[All Fields])))) AND ((("indoor"[All Fields] OR "indoors"[All Fields]) AND ("space"[All Fields] OR "space s"[All Fields] OR "spaces"[All Fields])) OR (("close"[All Fields] OR "closed"[All Fields] OR "closely"[All Fields] OR "closeness"[All Fields] OR "closes"[All Fields] OR "closing"[All Fields] OR "closings"[All Fields]) AND ("space"[All Fields] OR "space s"[All Fields] OR "spaces"[All Fields])) OR (("close"[All Fields] OR "closed"[All Fields] OR "closely"[All Fields] OR "closeness"[All Fields] OR "closes"[All Fields] OR "closing"[All Fields] OR	38	3

	"closings"[All Fields]) AND ("ventilated"[All Fields] OR "ventilates"[All Fields] OR "ventilating"[All Fields] OR "ventilation"[MeSH Terms] OR "ventilation"[All Fields] OR "ventilate"[All Fields] OR "ventilations"[All Fields] OR "ventilator s"[All Fields] OR "ventilators, mechanical"[MeSH Terms] OR ("ventilators"[All Fields] AND "mechanical"[All Fields]) OR "mechanical ventilators"[All Fields] OR "ventilator"[All Fields] OR "ventilators"[All Fields] OR "ventillation"[All Fields])))		
TRIP database	carbon dioxide monitor for covid-19	353	1 *
Clinicaltrials.gov	carbon dioxide monitor/CO2 measurement for covid-19	113	0
Epistemonikos	carbon dioxide monitor/CO2 measurement for covid-19	708	2*
medrixiv	carbon dioxide measurement for covid-19	262	2*
Google scholar	carbon dioxide monitor/CO2 measurement for risk assessment of covid-19		4

*Same study retrieved from other sources

Appendix 3: Characteristics of Included Studies

Initial review:

Title/Author	Study design	Country	Number of patients	Population	Intervention Group(s)	Control	Outcomes
Effect of Ventilation and CO2 concentration on TB transmission							
Du CR, Wang SC, YU MC, Chiu TF Wang JY, Chuang PC, Jou R, Chan PC, Fang CT. Effect of ventilation improvement during a tuberculosis outbreak in under ventilated university buildings. Indoor Air.2020; 30:422-432.	Retrospective Cohort study design (for all contacts in outbreak)			Evaluated 1665 contacts Acquired TB = 22 Did not have TB = 1643 Contact under CO2 >1000ppm +TB. -TB NO. 1 (4.6%). 722 (44%) YES. 21 (95.5%). 921 (56%) P<0.0001	Room <1000ppm CO2 Improving ventilation rate to 23.6-25.1 L/s/p (14-15 ACH) helped end the TB outbreak. Ventilation improvement to lessen CO2 to <1000ppm was associated	Room >1000ppm CO2	1/21 had TB infection in the INTERVENTION Group While 21/22 had TB infection in the CONTROL Group 97% decrease in infectious TB cases among contacts (95% CI: 50-99.9%) for those CO2 <1000ppm
Air Ventilation Protocol on CO2 concentration							

Di Gilio A, Palmisani J, Pulimeno M, Cerino F, Cacace M, Miani A, de Gennaro G. CO2 concentration monitoring inside educational buildings as a strategic tool to reduce the risk of Sars-CoV-2 airborne transmission. Environmental Research 2021. 202.111560. https://doi.org/10.1016/j.emvers.2021.111560.	Experimental, pilot study. *The premise is that indoor CO2 monitoring was suggested as a practical proxy of transmission risk of respiratory infectious disease. In indoor environments an excess of CO2 levels over outdoor levels could be related to the increased probability to inhaled breath exhaled by other people – thus to infection risk.	Italy	9 classrooms, 147-152 students	Students Pre-school	1st stage. Realtime CO2 monitoring 2nd stage. If CO2 levels approach 700 ppm, the following were done: Leave door open, open windows for 10min during breaks, open windows if the above don't work to lower CO2 levels.	No Protocols	Lowering of CO2 levels after instituting the protocol.
Vassella CC, Koch J, Henzi A, Jordan A, Waeber R, Iannccone R, Charriere R. From spontaneous to strategic natural window ventilation: Improving indoor air quality in Swiss Schools. Int J Hyg Environ Health. 2021. 113736.	Cross sectional	100 classrooms Range/classroom 3-26		CO2 levels decrease with increased ventilation and reminders for people to be aware of the benefits of ventilation compared to standard [no reminders/flyers on ventilations during breaks].	CO2 level Median: 1600pmm	CO2 level.Median: 1097 ppm Natural ventilation + mechanical + flyers, lessons on ventilation, + ventilation during breaks or open	

Lu Y, Li Y, Zhou H, Lin J, Zheng Z, Xu H, Lin B, Lin M, Liy L. Affordable measures to monitor and alarm nosocomial SARS-CoV-2 infection due to poor ventilation. Indoor Air. 2021; 00:1-10. Doi:10.1111/ina.12899.	Experimental Used CO2 levels as surrogate assessment method of noscomial infection risk. Prospective cohort: Case Study	Infrared CO2 sensors: Moderate [characterize exhaled breath]. +/- 50ppm. Measurement interval of 5 minutes [0.8-1.2m above ground]. Placed in the fever clinic [natural ventilation]; emergency department [mechanical ventilation] **CO2 level was used to estimate ventilation rates and can be diluted when ventilation rates are increased.	No infections were observed. No comparator. Infection among HCWs were just monitored and the airflow rate was noted at the time of the encounters with patients in different areas of the hospital based on number of infectors [Covid-19 patients]. Under the protection of level 2 PPE, an outdoor airflow rate of 21 L/(s·person) was sufficient to prevent SARS-CoV-2 hospital-acquired infection in Changgung Hospital. *Indoor CO_2 concentration represents the comprehensive effects of occupancy and the outdoor airflow rate. The ventilation can be sufficient to maintain a relatively low CO_2 concentration in an overrowded room, which is dangerous for diseases that can be transmit-ted through close contact, such as COVID-19.	In this study, aided with personal protection and disinfection measures, outdoor airflow rate per person of 15–18 L/(s·person) was sufficient to prevent nosocomial infection when there was only one COVID-19 patient, and 21 L/(s·person) was sufficient during throat swab sampling.	Theoretical determination of upper limit of CO2	Practical implications: The study showed that with personal protection and disinfection, the outdoor airflow rate per person of 15–18 L/(s·person) was sufficient to prevent nosocomial infection when there was only one COVID-19 patient, and 21 L/(s·person) was sufficient during throat swab sampling.

CO2 level and Sick Building Syndrome							
Dai-Hua Tsai, Jia-Shiang Lin & Chang-Chuan Chan (2012) Office Workers' Sick Building Syndrome and Indoor Carbon Dioxide Concentrations, Journal of Occupational and Environmental Hygiene, 9:5, 345-351, DOI: 10.1080/15459624.2012.675291	Cross-sectional study that used an SBS questionnaire and compared it to CO2 levels.	Correlate SBS [sick building syndrome] and CO2 concentrations -SBS, symptoms that cannot be associated with a well-defined cost but appear to be linked with time spent in a building.		CO2 concentrations are used as surrogate for indoor ventilation. SBS included eye irritation, headache, tiredness, fatique, tension, URTI, or GI complaints, skin irritations.	Used two time periods for questionnaire. Participants should be able to answer both.	CONCLUSION Indoor CO2 ≥800ppm were associated with an increase in workers' SBS, especially eye irritation and URTI.	+association between SBS and indoor CO2 levels: specifically [tired/strained eyes, dry/irriitated eyes, difficulty in remembering
Hou J et al. Associations of indoor CO2 concentrations, air temperature, and humidity with perceived air quality and sick building syndrome symptoms in Chinese homes. Indoor Air. 2021; 00:1-11.	Cross-sectional study Correlate CO2 levels with perception of dry air and skin SBS symptoms.			*CO2 was positively associated with the percentage of perceived stuffy odor. Low CO2 levels were less likely to have skin SBS symptom (dry facial skin, dry ears, dry hands)			

Title/Author	Study design	Country	Number of patients	Population	Intervention Group(s)	Control	Outcomes
Ventilation and CO2 Concentration as functions of aerosol spread							

Vernez D, Schwarz S, Sauvain JJ, Petignat C, Suarez G. Probable aerosol transmission of SARS-CoV-2 in a poorly ventilated courtroom. Indoor Air. 2021 Nov;31(6):1776-1785. doi: 10.1111/ina.12866. Epub 2021 Jun 11. PMID: 34115411; PMCID: PMC8597151.	Case study	Switzerland		10 courtroom attendees	Simulation of the courtroom setting		Higher emission rates and longer event duration were associated with increased probability of infection. Air renewal rate was measured using CO2 levels as function of time. Their mathematical model described that the air renewal rate has a significant role for event durations > 0.5 hr and that transmission probability decreased with opened windows.

Huessler EM, Hüsing A, Vancraeyenest M, Jöckel KH, Schröder B. Air quality in an air ventilated fitness center reopening for pilot study during COVID-19 pandemic lockdown. Build Environ. 2022 Jul 1;219:109180. doi: 10.1016/j.buildenv.2022.109180. Epub 2022 May 13. PMID: 35581988; PMCID: PMC9098400.	Observational pilot study	Germany	There were a total of 4,232 people in the entire fitness center during the study period.	Fitness center attendees	Air quality measurements	No Protocols	CO2 concentrations in different time periods. Correlation of the number of visitors in the fitness center to the predicted CO2 concentration
Somsen GA, Winter MM, Tulevski II, Kooij S, Bonn D. Risk of aerosol transmission of SARS-CoV-2 in a clinical cardiology setting. Build Environ. 2022 Jul 15;220:109254. doi: 10.1016/j.buildenv.2022.109254. Epub 2022 Jun 11. PMID: 35719131; PMCID: PMC9187860.	Observational	12 patients		12 patients who underwent CEST	Air quality measurements: aerosol presence and CO2 levels	Aerosol concentration increased with increasing CO2 levels. In well-ventilated room, the aerosol concentration and CO2 levels declined after the stress test stopped. In the low ventilation setting, the aerosols persist and CO2 level remained high even at 5 mins after the cessation of stress test.	
Estimating risks and magnitude of secondary COVID-19 infection							
Title/Author	Study design	Country	Number of patients	Population	Intervention Group(s)	Control	Outcomes

Burridge, H. C., Fan, S., Jones, R. L., Noakes, C. J., & Linden, P. F. (2021). Predictive and retrospective modelling of airborne infection risk using monitored carbon dioxide. *Indoor and Built Environment*. https://doi.org/10.1177/1420326X211043564	Data modelling	UK	40 people for 8 hours each day	Adult room occupants			Doubling the ventilation rate per person decreases the likelihood of airborne infection to 0.6%, and decreasing the outdoor air supply rate per person to ~20% results in 3.6-fold increase in airborne infection risk. Reducing the occupancy by a factor of r results in the expected number of secondary infections that might arise via the airborne route being reduced by a factor r^2 for all the scenarios considered herein.

Rodríguez D, Urbieta IR, Velasco Á, Campano-Laborda MÁ, Jiménez E. Assessment of indoor air quality and risk of COVID-19 infection in Spanish secondary school and university classrooms. Build Environ. 2022 Dec;226:109717. doi: 10.1016/j.buildenv.2022.109717.	Cross-sectional	Spain					Despite IAQ inside the classrooms being good, the estimated transmission risk (Hr) for COVID-19 ranged from intermediate (with surgical masks) to high (no masks, teacher infected). Controlled mechanical ventilation systems and wearing well-fitting FFP2–N95 masks indoors contributed to the decrease transmission risk of COVID-19 (AR 35%/50%, without masks for Alpha and Omicron BA.1 to 20%/30% with mask)

Costanzo S, Flores A. COVID-19 Contagion Risk Estimation Model for Indoor Environments. Sensors (Basel). 2022 Oct 9;22(19):7668. doi: 10.3390/s22197668.	Cross-sectional: application of infection risk modelling using a mobile app	Italy	The number of people present was assumed as follows: • Classroom =42 • Restaurant = 280 Library =20 Mall = 400 Office = 10	Occupants assumed age range for all cases is from 21 years up to 31 years.	Use of Android app: COVID risk estimator		Application allowed for measurement of permanence time, maximum allowed number of people for the specified area, the expected number of COVID-19 cases, and the required number of air changes per hour in an area
Tang H, Pan Z, Li C. Tempo-spatial infection risk assessment of airborne virus via CO2 concentration field monitoring in built environment. Build Environ. 2022 Jun 1;217:109067. doi: 10.1016/j.buildenv.2022.109067.	Case study	China	3 occupants	Office occupants	Evaluation of the tempo-spatial distribution of infection risk in built environment via real-time CO2 field measurement		individual infection risks diversified with different dwell times

Carbon dioxide monitors as guide for improving ventilation							
Title/Author	Study design	Country	Number of patients	Population	Intervention Group(s)	Control	Outcomes
Laurent MR, Frans J. Monitors to Improve Indoor Carbon Dioxide Concentrations in the Hospital: Background, Rationale and Protocol for a Randomized, Sham-controlled, Cross-Over, Open Label Trial. Available from: https://pubmed.ncbi.nlm.nih.gov/34728206/	Randomized cross-over trial	Belgium	97 women and 30 men in two geriatric wards	Geriatric ward patients	CO2 sensor reading displayed	CO2 sensor reading not displayed.	Baseline median time per day with CO2 concentration > 800 ppm was 110 min vs. intervention), 82 min in the control/no CO2 monitors, and 78 min in the intervention period. CO2 levels >1000 ppm was noted for 2 min at baseline and 0 min in both control and intervention; while levels >1400 ppm was noted only for 3 min in one day in one room. The differences in the outcomes between control and intervention groups were not significant (P = 0.77, P = 0.052 and P = 0.22, respectively)

							Staff members (N = 32 anonymous survey respondents) gave high ratings (median 8/10) for feasibility and preference to use CO2 monitors. The main barriers for implementation were cold discomfort for patients (N=19, 59%), lack of visibility and attention drawn by themonitors (N=5) and risk that the patientwould fall out of an openwindow (N=4)

Appendix 4: Risk of Bias of included studies

Author(s): Mark Jason DC. Milan, MD, Emmanuel P. Estrella, MD, MSc, Maria Teresa S. Tolosa, MD, D Clin Epi, FPDS Myzelle Anne Infantado, PTRP, MSc (cand.)
Question: CO_2 levels below 1000ppm versus =/> 1000ppm
Setting: Community or healthcare setting
Bibliography: Du CR, Wang SC, YU MC, Chiu TF Wang JY, Chuang PC, Jou R, Chan PC, Fang CT. Effect of ventilation improvement during a tuberculosis outbreak in under ventilated university buildings. Indoor Air.2020; 30:422-432.

		Newcastle Ottawa
Du et al (2020)	Retrospective cohort	★★★★★★★★
Di Gilio (2021)	Experimental	N/A
Lu et al (2021)	Experimental	N/A
Vernez et al (2021)	Case study	N/A
Tang et al (2022)	Case study	N/A
Burridge et al (2021)	Data modelling	N/A

NIH Quality assessment Observational and cross-sectional studies	Research question	Study population	Participant rate at least 50% from eligible	Participants from same/similar population	Sample size justification	Exposure(s) measured prior to outcome(s)	Sufficient time frame	Examination of different levels of exposure as related to the outcome	Definition and validation of the exposure measures	Exposure(s) assessed more than one	Definition of outcome measures	Blinded assessors	Lost to follow-up after baseline of 20% or less	Statistical measure and adjustment of key confounding variables
Vassella (2021)	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	N	NA	NA
Tsai et al (2021)	Y	Y	Y	Y	N	Y	NA	NA	Y	N	Y	N	NA	NA
Hou et al (2021)	Y	Y	Y	Y	N	Y	NA	NA	Y	N	Y	N	NA	NA
Huessler et al (2022)	Y	Y	Y	NA	NA	NA	Y	NA	Y	N	Y	N	NA	NA
Somsen et al (2022)	Y	Y	Y	Y	N	NA	Y	NA	Y	N	Y	N	N	NA
Rodriguez et al (2022)	Y	Y	Y	Y	N	NA	Y	NA	Y	N	Y	N	N	NA
Costanzo et al (2022)	Y	Y	NA	NA	N	Y	Y	Y	Y	N	Y	N	N	N

Appendix 5: GRADE Evidence Profile

Author(s): Mark Jason DC. Milan, MD, Maria Teresa S. Tolosa, MD, D Clin Epi, FPDS
Question: Carbon dioxide monitoring compared to no carbon dioxide monitoring for decreasing COVID-19 risk
Setting: Hospital Setting
Bibliography: Laurent MR, Frans J. Monitors to improve indoor air carbon dioxide concentrations in the hospital: A randomized crossover trial

Certainty assessment							Impact	Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations			
Median time per day with CO_2 > 800 ppm									
1	randomised trials	not serious	not serious	serious	not serious	none	The median time per day with CO_2 concentration > 800 ppm was 110 min (7.6% of the day; IQR 47–207 min) at baseline. Control period: 82 min (5.7%, IQR 12–226.5 min, P > 0.99 vs. intervention). Intervention period: 78 min (5.4%, IQR 20–154 min). Post-intervention: 140 min (9.7%, IQR 19.5–612.5 min, P = 0.0167).	Moderate	IMPORTANT
Median time per day with CO_2 > 1000 ppm									
1	randomised trials	not serious	not serious	serious	Not serious	none	The median time per day with CO_2 levels > 1000 ppm was 2 min (IQR 0–19) at baseline The median time per day was 0 min (IQR 0–20, P = 0.2366 vs. intervention) in the control periodThe median time was 0 min (IQR 0–2) during intervention and 0 min (IQR 0–57) post-intervention. The median daily peak CO_2 concentration was 1010 ppm (IQR 926.5–1086, P = 0.0010) at baseline, 964 ppm (IQR 846–1075, P = 0.5143) during the control period, 932 ppm (IQR 861–1002) during intervention, and 977.5 ppm (IQR 873.5–1127) post-intervention.	-Moderate	IMPORTANT
Median time per day with CO_2 > 1400 ppm									
1	randomised trials	not serious	not serious	serious	not serious	none	CO_2 concentrations exceeding 1400 ppm were only observed during the post-intervention period, for 3 min on one day in one room and for a total of 202 min over four days in another room (out of 12 total rooms).	Moderate	IMPORTANT

CI: confidence interval