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A rapid review of the use of physical barriers in non-clinical settings and COVID-19 transmission

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Key Messages

- Epidemiological and experimental evidence suggests that physical barriers may decrease transmission risk. However, challenges in creating clear guidance around barrier design and implementation, and in studying the effect of barriers in the real world, make it difficult to assess their effectiveness.
- Physical barriers serve a specific, but limited, purpose. They are intended to prevent the rapid bi-directional exchange of respiratory particles that occurs when two people interact in close proximity.
- Barriers do not kill or substantially remove the virus from the air. However, by redirecting respiratory emissions away from the breathing zone, other ventilation and air cleaning assets are given time to reduce particle concentration. Barriers must be paired with good ventilation, as their actions are complementary.
- Barriers are not appropriate in all settings; they are dictated by occupant activities and interactions. Barriers are most valuable for people who have high frequency but short duration interactions with high-risk contacts. They will be less valuable in settings with long-duration contacts, particularly in the absence of ventilation.

Introduction

In March 2020, physical barriers or partitions made from glass, plastic, or plexiglass became a key component of the initial public health response to the pandemic and were nearly ubiquitous in public indoor spaces. Initially, very little guidance or evidence was available on how to use barriers to control a respiratory disease outside of clinical healthcare settings. Given the vast array of non-clinical settings being considered, early work in this area started from logical assumptions about how COVID-19 spreads, how members of the public might have to interact with each other, other available public health measures (e.g., masking), as well as previous infection prevention and control experience in clinical settings.

As the pandemic has progressed, physical barriers have become fixed features in some environments, whereas their utility in others has been questioned.[1] The pandemic has also changed the ways in which we view public spaces, and some of the protective measures and practices that have been implemented may be useful as we try to construct a more pandemic-resilient future.[2] What have we learned about the role of barriers in our COVID-19 prevention plans? This rapid review looks at 1) the existing guidance or recommendations on implementing physical barriers in various non-clinical settings and 2) the evidence on their effectiveness in preventing COVID-19 transmission, alone or in combination other public health measures.

Literature search methodology

For our review of past recommendations, Google and the websites of major public health agencies were used to search for guidance documents on the implementation of physical barriers. More than 30 websites and documents on how to implement physical were identified. These were used to understand past practices/recommendations only; they were not appraised or evaluated, and only the most substantive of those documents are discussed here.

Next, we searched the scholarly and grey literature for evidence on the effectiveness of physical barriers using the EBSCOhost databases (includes Medline, CIHAHL, Academic Search Complete, ERIC, etc.), Google Scholar, and Google. Relevant English-language results were collected from May 2020 to November 2021; additional references were added via forward and backward chaining of those search results. Complete search terms and the full list of results are available upon request. Studies were selected for review if they described the use of screens, partitions, or barriers used as a public health measure in a non-clinical setting. Both peer-reviewed and pre-print sources were considered. Medical letters regarding the use of improvised screens or containment for aerosol-generating medical procedures were excluded because they do not represent the types of exposures that occur in non-clinical settings.

Thirteen primary studies (pre-prints or peer-reviewed) and two syntheses[3,4] from the grey literature were available for review. Seven studies examined the effects of physical barriers in virtual or physical models. A **virtual model** refers to the use of computational fluid dynamics (CFD) or other tools to model the movement of particles in a virtual space. A **physical model** refers to the creation of an exposure chamber, mimicking an office, classroom, or other space occupied by mannequins. A cough simulator is then used to examine particle transport and fate in a non-virtual but highly controlled environment. Virtual models are often validated from physical models; some studies provide both. Six observational studies assessed the effectiveness of physical barriers in the real world. Each study was assessed by a single reviewer and the results were synthesized narratively. The synthesis was subjected to internal and external review.

Results

What were the initial objectives and recommendations around physical barriers?

In May 2020, the NCCEH published the results of a rapid consultation with technical experts, industry professionals, and infection prevention and control specialists on the use of physical barriers in COVID-19 safety plans.[5] The aim of this document was to support public and occupational health agencies when integrating physical barriers into COVID-19 health and safety planning. Since then, numerous other agencies have published detailed guidance on the use of physical barriers, which can be used to understand the objectives and knowledge gaps around their adoption as a public health measure. However, although numerous documents and websites were identified in this review, only a handful dealt substantively with how to implement physical barriers (**Table 1**).

Table 1. Examples of some of the more comprehensive guidance on physical barriers.

Agency	Settings Considered
National Institutes of Health (n.d.). Proper Use of Barriers (Plexiglass/Lexan) in the Workplace.[6]	General occupational settings, including laboratories.
US Centres for Disease Control and Prevention (n.d.). Strategies for Protecting K-12 School Staff from COVID-19[7]	The only major public health guidance that focusses on the school environment and advises for the use of physical barriers in classrooms.
University of Washington (Oct 2020). Guidance for plexiglass barriers in support of COVID-19 prevention efforts[8]	"High volume stations" within the university environment where frequent contacts are occurring; classrooms not considered.
WorkSafeBC (May 2020). COVID-19 health and safety: Designing effective barriers.[9]	General occupational settings, including shared vehicles.
McMaster University (July 2020). Guidelines for the Use of Physical Barriers During COVID-19 Pandemic[10]	Workstations with high frequency contact where distance cannot be maintained, vehicles, shared spaces in libraries; classrooms not considered.
Southwestern Public Health (Sept 2020). Physical Barriers to Prevent the Spread of COVID-19[11]	Bars, restaurants, offices, checkout counters and reception desks, shared spaces in schools not restricted to one cohort.

The key initial objectives for barriers and caveats for their use are summarized in **Box 1.** This synthesis of objectives and caveats is provided to clarify the original intent behind guidance documents and to identify where or how those objectives may not have been clearly communicated.

Box 1: Key objectives and caveats for the use of physical barriers in public settings.

Based on these documents, the stated or implied objectives of using physical barriers in a public setting included:

- Blocking the direct or immediate flows of respiratory particles moving from one person to another, which might otherwise be entrained/inhaled or settle on the face or other surfaces;
- Protecting individuals who must engage in close proximity interactions with people whose infection status is unknown (high risk contacts);
- Protecting workers specifically, rather than members of the public, as on-site workers will have a higher cumulative daily exposure than others passing through the space;
- Permitting interactions in clinical or pedagogical settings where seeing the entire face is necessary;
- Serving as a visual reminder that distancing is required, and in some cases enforcing distancing and/or making crowding impossible.

Potential issues or risks arising from the use of physical barriers:

- Physical barriers are not intended to control smaller particles that do not settle or might accumulate in the space;
- Barriers must be wide and tall enough to protect workers, without blocking ventilation;
- It is still necessary to ventilate the space and to avoid blocking ventilation assets;
- Ergonomic issues may arise as employees change their posture or habits to accommodate the barrier, or may move around the barrier to speak;[8]
- Barriers may require people to speak more loudly, especially when masked;
- Barriers must not block or impede escape in case of an emergency, and must not violate building or fire codes;
- Barriers should be used in conjunction with other public health measures as much as possible;
- Materials used must be easy to clean and disinfected regularly.

One potential gap in communication concerns adapting physical barriers to different settings. Most guidance documents considered a general occupational setting, with only brief mentions of specific settings or how to accommodate different situations, such as standing or sitting (or both).[8,9,11] Only one guidance document recommended the use of barriers in classrooms specifically, but offered few details.[7] Other guidance documents mentioned the use of partitions in school environments, but not in classrooms. Instead, barriers were recommended for staff with high-frequency interactions or in shared indoor spaces of the school where students from different cohorts had to interact (e.g., library).[8]

What can we learn from virtual and physical models about the role of barriers in preventing COVID-19 transmission?

Studies based on virtual or physical models are useful because they allow the researcher to control factors that might vary substantially in real-life settings, such as the location of the source, the type and rate of mechanical ventilation, and the number and placement of other occupants. This simplified environment makes it easier to examine how partitions affect the flow of particles in a room, deposition onto surfaces and people, and clearance of aerosols from the room. Virtual and physical models can also be used to look at the complementary role of other public health measures such as masking, distancing, enhanced ventilation, opening windows, air cleaners, etc.

Abuhegazy et al.[12] used CFD modelling to examine the effect of 70-cm tall cubicles on particle transport when installed on the desks of a classroom containing nine students. The barriers reduced the number of aerosol particles travelling from one infected student to the eight other students by 92% on average and reduced deposition onto other students by 63%, but the presence of the barrier also slowed clearance from the room. Similarly, Mirzaei et al.[13] tracked the flow of more than 10,000 respiratory particles (0.150–150 μm) in a class of 30 students after a single cough from an infected instructor. The presence of desktop partitions again increased the amount of time required for all emitted droplets to settle or clear out of the room, but also reduced the total particles to which each student was exposed. Combining partitions with increased airflow further decreased exposure to particles and reduced the time required to clear particles.

Ren et al.[14] developed a CFD model of an open-plan office occupied by 43 people and examined the effect of 40–70-cm barriers on particle dispersion and infection risk. Barriers 60 cm or higher were most effective in reducing dispersion of the particles throughout the room; a 60-cm barrier provided a 72% reduction in transmission risk. However, the location of the index case in the room mattered: the farther the source was from the outlet or room exhaust, the less effective barriers were at reducing dispersion and infection risk.

Similarly, Bartels et al.[15] simulated a customer coughing on a worker, with and without a barrier, and found that the medium-sized barrier (ending approximately 40 cm above a person's mouth) was most efficient in terms of reducing the number of particles reaching the worker's breathing zone. There was no additional benefit to having very tall barriers, and the largest barrier in the simulation may have interfered with room airflow. Similarly, Ye et al.[16] found that a barrier height that came up to at least 3–5 cm above the person's mouth was enough to limit the lateral spread of that person's expiratory jet.

One of the key concerns with physical barriers is that they are more likely to provide protection against larger particles than smaller particles, especially as time spent in the space increases. The studies above examined a very brief period of time (< 15 min), which is sufficient to analyze dispersion and infection risk from a single cough or sneeze from a single source. This simplified model may be more applicable to settings where healthy workers have numerous short interactions during a day and customers do not linger (e.g., retail). However, these models are less applicable in settings where people share the space over a prolonged period (e.g., offices or classrooms), or when there is a greater likelihood of having more than one source in the room, as during periods of high community transmission.

This is a particular concern in classrooms, where exposure duration is prolonged, masking fit and compliance are variable, and covering the face may create challenges in communicating with young children. Epple et al.[17] simulated a classroom using fog-emitting mannequins and aerosol sensors to look at the protective effect of masking, physical barriers, window opening, and personalized ventilation. Masking alone resulted in the neighbouring "students" being quickly exposed to aerosols that escaped the mask. However, adding a partition prevented aerosol exposure for about 10–13 minutes, at which point the fog began to overtop the source cubicle, contaminating those to the left and right. To address this, the authors also tested the use of a personalized ventilation system, in which flexible aluminum tubing suspended above each desk suctions air from the top of the cubicle, which greatly reduced aerosol accumulation within the cubicle (qualitative analysis only).

Restaurants also present unique challenges. Because people must remove their mask to eat, and eating may also be associating with socializing, tabletop dividers or cubicles have become a key measure to block the exchange of respiratory particles. Body heat and the heat of the food itself can also facilitate the rise and spread of respiratory particles.[16] Liu et al.[18] created two CFD models to look at the effect of multiple sources with or without partitions in two dining rooms over a 30-minute period. They compared a larger cafeteria with 1.8 m occupant spacing (ventilated at 19.5 ACH) with a narrow, more densely occupied restaurant ventilated at 9.1 ACH. The placement of barriers throughout the space impeded mixing driven by the room's air supply, which reduced the lateral movement of aerosols. However, risk throughout the space varied depending on the positions of both the source and the other diners: most customers saw decreases in risk, but some experienced small increases in risk. Overall, infection risk was much lower in the larger, better ventilated space and barriers had little impact, most likely because of better spacing between diners (1.8 m apart). In contrast, the presence of barriers had a more positive (but still small) effect in the narrower, less-ventilated space.

Another concern is that diners may occupy the same seat or cubicle in quick succession, such that particles exhaled by the previous occupant are inhaled by the next. Liu et al.[18] looked at how the diner's own exhaled breath might accumulate within the cubicle under specific airflow conditions when barriers are in place. They determined that barriers did lead to accumulation, but that waiting for at least six minutes before reoccupying the seat caused infection risk to drop from approximately 4.5% to less than 1%. Similarly, Ye et al.[16] reported that table-top barriers resulted in the accumulation of exhaled breath, and that the effect was stronger for tables with "cross partitions" than for linear partitions extending down the length of the table only. It took 11 minutes for this accumulation of exhaled breath to decrease to background levels, although the greatest risk reduction (80–90%) occurred in the first two to three minutes. Both studies concluded that partitions were valuable for reducing (but not eliminating) infection risk to neighbors, but they also created a small risk for subsequent diners over the time frames studied. However, even this small risk might have been negated if the models had accounted for the random movements of occupants and subsequent effects on mixing.

Generally, the studies reviewed here reported an overall positive impact of installing barriers. They can reduce (but not eliminate) lateral spread, and the benefits are greatest for the nearest neighbors, rather than those far away or on the same side of the barrier. In addition, the models are useful to demonstrate the high degree of heterogeneity within indoor environments. It is not always possible to visually assess an individual's risk, as factors like the configuration and flow rate of the ventilation system and the ability of barriers to either impede or accentuate airflow can result in unpredictable pockets of high or low risk.[18]

The virtual and physical models described above also have several limitations, which may result in their overall benefit being overestimated. They examine exposures lasting less than half an hour, which are less helpful to understand infection risk in settings such as classrooms or offices. They do not account for speech — especially loud speech in a noisy venue — which would increase particle emission. They do not account for factors like people moving in their seats, turning their heads, or moving about the room, which would affect mixing and could increase or decrease the chance of exposure. Finally, the CFD models in particular do not account for passive infiltration and exfiltration of air from the space, which may then affect the degree of dispersion throughout the room.

What does the evidence say about partitions in real-world settings?

In contrast to virtual and simulated environments, evidence from the real-world is both less available and more difficult to interpret. Because physical barriers are almost universally implemented as part of a suite of public health measures, as recommended, it can be difficult to assess their individual contributions to preventing transmission. In addition, how data are collected can make it difficult to know whether specific measures have been implemented properly or observed.

Two recent studies from the US relied on survey data to try to assess the effectiveness of individual measures in schools. Gettings et al.[19] used survey data from 169 K–5 schools in the state of Georgia, to examine the association between in-school COVID-19 incidence and public health measures in school classrooms, such as masking, flexible medical leave, improved ventilation, distancing, and using barriers on desks. Responses were collected from November through December 2020. Mandatory masks for teachers and staff (but not students) and combining dilution ventilation with air filtration both appeared to decrease the incidence of COVID-19 associated with schools. In contrast, schools using physical barriers on desks or tables in all classrooms (n = 38 schools) showed no decrease in the relative risk of COVID-19 incidence compared with schools using barriers on desks is some or no classrooms. This would suggest that barriers did not help in reducing transmission. However, when analyzing data for ventilation improvements, there was no difference in COVID-19 incidence for those schools reporting ventilation improvements versus those that did not know whether ventilation had been improved. This highlights the issues with using self-reported data: both the implementation of measures and reporting on them was left in the hands of non-experts, which can create greater uncertainty in interpreting those data.

Similarly, Lessler et al.[20] used data from the Facebook-based COVID-19 Symptom Survey to examine the association between COVID-like illness or test positivity in children and individual mitigation measures used in their schools. The largest decreases in risk were observed for daily symptom screening, teacher mask mandates, and cancelling extra-curricular activities. Many other common measures such as student masking, distancing, cohorting, and reducing class sizes showed no effect. Some measures, such as the use of physical barriers on desks, outdoor instruction, and indoor play tended toward an increased risk of COVID-like illness. The most important lesson from this research, however, was that layering preventive measures did significantly reduce COVID-19 risk. Each additional measure led to an additional 9% decrease in the risk of COVID-19-like illness; by implementing seven or more measures, the risk of COVID-19-like illness was reduced to the level of at-home learning. Although the data set was large (> 500,000 respondents), it is limited by the fact that data on mitigation measures were reported by parents, who are generally not present in the classroom and not knowledgeable about how to implement measures appropriately.

Only three studies were available that examined the COVID-mitigating effect of physical barriers based on on-site, expert assessment. Doron et al.[21] looked at an outbreak that was initiated in a school office. Potential contributing factors including eating together unmasked, shared office space and high traffic areas. The authors also examined airflow in the space using smoke testing and determined that physical barriers present may have impeded air mixing. The plexiglass barriers were not removed, but rather shifted to allow better air flow.

In Japan, Ishigaki et al.[22] used a tracer gas (CO_2) to investigate airflow in an office recently involved in an outbreak. Management had used plastic sheeting to divide the unventilated office space into five zones, each of which had three to eight masked occupants. During the outbreak, cases were clustered together within three zones, while the other two neighbouring zones were unaffected. Windows were kept closed due to winter weather and a single door was the only means of airflow. Although the partitions did not reach the ceiling, they were high enough that CO_2 gas accumulated within each compartment, suggesting that these dividers may have enhanced transmission within the compartment, while preventing spread to neighbouring unaffected compartments. It should be noted that using partitions to enclose several people within an unventilated space is counter to public health recommendations.

Perhaps the most informative assessment of the effects of physical barriers on COVID-19 risk comes from meat-packing facilities. Meat-packing facilities have been heavily impacted during the pandemic due to indoor environmental, occupational, and even socio-cultural factors that increased interpersonal exposure and facilitated the spread of the virus.[23] Temperature screening, masking, and physical barriers are some of the most common preventive measures based on surveys of facilities.[24,25]

Herstein et al.[26] attempted to quantify the effects of masking and physical barriers on COVID-19 incidence in 13 such facilities. Of the 11 facilities that instituted both masking and physical barriers, COVID-19 incidence decreased significantly in eight facilities, increased in one, and showed no change in two facilities. Three of the facilities also collected enough data to examine the differential impacts of instituting masking first, and then physical barriers after a sufficient interval. In two of these facilities, adding physical barriers to masking drove a large additional decrease in COVID-19 cases. In the third facility, masking alone was enough to drive down COVID-19 incidence; physical barriers had no additional benefit. Only two facilities instituted masking alone (no barriers), and neither saw a significant decrease in COVID-19 incidence over the study period.

Taken together, these data suggest that installing physical barriers had an additional effect on reducing COVID-19 transmission in meat-packing facilities.[26] Although relatively few facilities (n= 13) were included in the study, the researchers visited each site, allowing better assessment of implementation and compliance. However, masking and barriers were not sufficient to completely prevent transmission when used alone or together. This is expected given the many factors that may affect transmission and lead to outbreaks, including changes in behavior both inside and outside the plant that may not have been captured in the study. Furthermore, masks and barriers are not always used simultaneously (e.g., in the lunchroom vs. the production line), so the effect of barriers may not have been “in addition to” masks if transmission was driven by mealtimes.

In contrast to the kind of long-duration exposures experienced in classrooms and some workplaces, community pharmacists have relatively short contact with clients, but are more likely to encounter multiple infected individuals throughout the day. Survey data from three Middle Eastern nations found that community pharmacists who worked without a physical barrier had a 2.2-fold higher risk of contracting COVID-19, after adjusting for other factors.[27] These data support public health recommendations that physical barriers are most appropriate for short-duration, high frequency contacts.

Summary

The evidence reviewed here suggests that physical barriers may be effective in reducing overall exposure to respiratory particles. However, the literature raises a number of concerns. A rapid scan of the public health guidance shows that very few online resources deal substantively with how to implement barriers, perhaps because of the complexity of indoor spaces and the difficulty in devising such guidelines. However, it also appears that the basic objectives for using barriers are not clearly understood, leading to counterproductive actions (e.g., enclosing several people within barriers) and use in inappropriate settings (e.g., classrooms). In addition, key requirements such as the need for complementary ventilation have not been observed. These issues are unsurprising given the extremely rapid rate at which barriers were implemented in diverse workplaces and public spaces, often without technical assistance or specific guidance, and given the evolving understanding of how COVID-19 is transmitted.

Despite issues with implementation, physical barriers may still offer benefits in specific situations or settings, both during this pandemic and in the future. Further research is needed to understand the magnitude of their potential effect on disease transmission. Ideally, public health interventions with the greatest magnitude of effect would be implemented first. Because of difficulties with implementing barriers correctly, barriers may not rank highly on that scale. In addition, the relative value of barriers will be greater in some settings than in others; future research should compare effectiveness across settings, particularly in restaurants where masking is not possible. Finally, given the renewed interest in how humans share the air, it may be useful to consider what role barriers might play in pandemic-resilient workplaces of the future.

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