

Nursing Home Adoption of CDC and ASHRAE COVID-19 Built Environment Recommendations: A Characterization Study of Colorado Nursing Home Facilities

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Abstract

Background: During the COVID-19 pandemic, the Centers for Disease Control and Prevention (CDC) and ASHRAE provided infection control recommendations for the built environments and ventilation systems of nursing homes (NHs). The level of adoption of the suggested strategies is unknown, as little information has been obtained from NHs identifying the strategies that were implemented. **Objective:** The primary goal of our study was to characterize the built environments of Colorado NHs during the COVID-19 pandemic to assess the level of adoption of CDC and ASHRAE recommendations. Our secondary goal was to identify opportunities and barriers that NHs face as they work to create health-protective built environments in the future. **Method:** We used the Nursing Home Built Environment survey to obtain data related to three main categories of CDC and ASHRAE recommendation for Colorado NHs: Resident Isolation, Improved Indoor Air Quality, and Staff Separation/Support. **Results:** Key findings included: (1) On average, NHs had 34% of their beds located in single-occupancy rooms; (2) seven (9%) NHs had designated COVID-positive “neighborhoods”; (3) 14 (20%) NHs had common area ventilation systems that were utilizing filters with a minimum efficiency reporting value 13 rating, or higher. **Conclusion:** Most Colorado NHs did not fully implement the COVID-19 built environment strategies recommended by CDC and ASHRAE. While there are barriers to the adoption of many of the strategies, there are also opportunities for

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immediate improvements that can support the health of vulnerable NH populations as we continue to see high rates of aerosolized infectious disease spread in NH facilities.

Keywords

nursing home, long-term care, built environment, COVID, ventilation

The impact of the COVID-19 pandemic on nursing home residents has been overwhelming not only due to the rates of morbidity and mortality, but also due to the disruption of normal activities and increased stress on residents and staff. When we conducted our survey of Colorado nursing homes in November of 2020, 149 (66%) of the licensed nursing homes (NHs) in Colorado reported COVID-19 resident cases. By the time the Centers for Disease Control and Prevention (CDC) revised their guidance and Colorado lifted the mask mandate in May 2021 (Centers for Disease Control and Prevention [CDC], 2021a), 217 (98%) nursing homes in Colorado reported COVID-19 cases. While COVID-19 cases in NHs only represented one percent of the total cases in the state, 27% of COVID-19 deaths in Colorado were residents in NH facilities (Colorado Department of Public Health and Environment [CDPHE], 2021; Centers for Medicare & Medicaid Services (CMS), 2021). The rates of COVID-19 infection and death demonstrate the vulnerability of the populations who reside in NH environments. Prior to COVID-19, NHs frequently faced infectious disease outbreaks, including influenza and norovirus (Utsumi et al., 2010), and they will continue to be impacted by these and other infectious diseases in the future. Built environment strategies recommended for infection control during COVID-19 can be used as strategies for best practices for infection control in Nursing Homes in the future.

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Built environment (BE) strategies to limit the spread of COVID were created by CDC as well

ASHRAE (previously named the American Society of Heating, Refrigerating, and Air-Conditioning Engineers). The recommendations include strategies to isolate residents, improve ventilation, and physically separate staff. Despite evidence to support the recommendations (Belo et al., 2019; Friesema et al., 2009), there is limited information regarding whether or not NHs utilized the various strategies during the pandemic. This is a gap in knowledge that needs to be addressed because assessing the level of implementation, and the associated feasibility of the strategies, is the first step in identifying obstacles to their implementation in the future.

Significance

The adoption of BE strategies has relevance not only during the COVID pandemic, but also as we continue to address infectious disease spread in facilities that serve vulnerable populations. According to CDC's Weekly Influenza Surveillance Report, rates of infection and mortality were significantly lower during the 2020–2021 influenza season than in previous years (**Figure 1**). This unintended positive outcome of the pandemic can inform our strategies to prevent disease spread in the future. While primary infection prevention strategies like resident isolation and continued use of PPE may be challenging due to the physical and emotional toll they take on NH residents and staff, BE infection-control strategies have the potential to be sustainable, health-protective, and health-promoting (Agronin, 2020; Anderson et al., 2020; Wu, 2020).

Aim/Purpose

The goal of our study was to characterize the built environments (BEs) of Colorado nursing homes during the COVID-19 pandemic to better

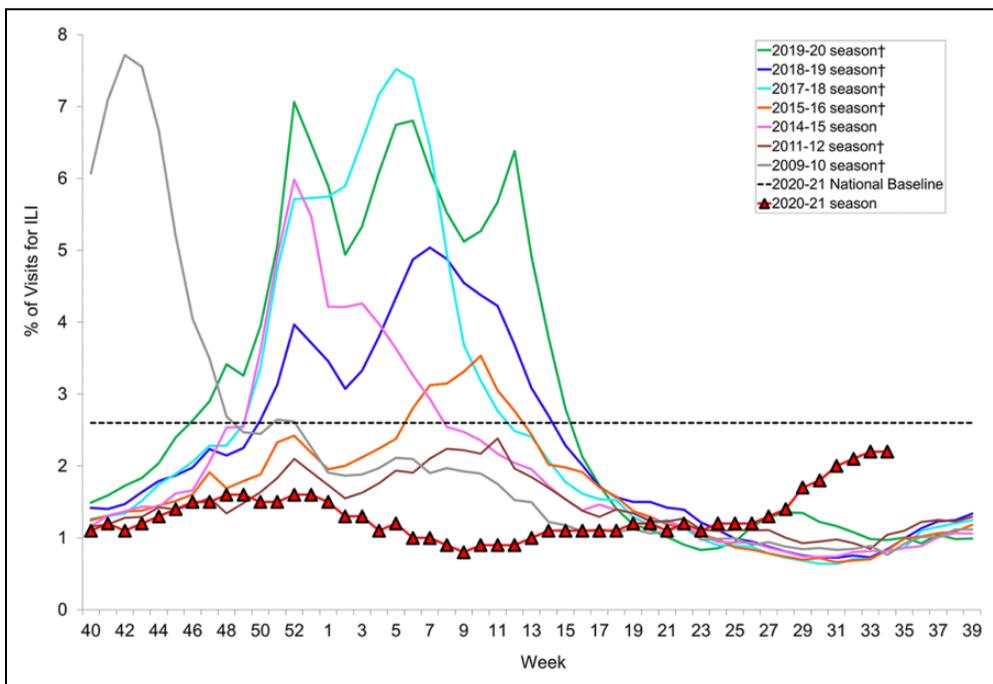


Figure 1. Percentage of visits for influenza-like illness reported by the U.S. Outpatient Influenza-like Illness Surveillance Network (ILNet), weekly national summary 2020–2021, and selected previous seasons. *Source:* Adapted from Weekly U.S. Influenza Surveillance Report, 2021 (<https://www.cdc.gov/flu/weekly/index.htm>).

understand the level of implementation/adoption of built environment pandemic recommendations and identify opportunities and barriers that nursing home facilities face as they continue to work towards creating residential care environments that are both health-protective and health-promoting.

Review of COVID BE Guidelines

The CDC's built environment recommendations, which were not specific to NHs or long-term care facilities (LTCF), included the following: (1) increasing outdoor air ventilation, (2) decreasing occupancy in areas where outdoor ventilation could not be increased, (3) taking steps to ensure ventilation systems operated properly, and (4) improving air filtration (CDC, 2021b). For nursing homes, the CDC specifically recommended that during the pandemic residential units be limited to one occupant per space and that dedicated COVID units be created within care facilities (Table 1). CDC (2021c) ASHRAE guidance for

LTCFs during the pandemic included the following: (1) providing areas for staff donning/doffing of PPE, (2) providing areas for staff respite, (3) improving levels of filtration, (4) utilizing/creating relative air pressure differences to direct air flow, (5) increasing dilution by increasing outside air, and (6) increasing filtration levels; (7) maintaining 40%–60% relative humidity (Table 1; ASHRAE, n.d.; Stuart, 2020).

Method

In August 2020, a collaborative working group was formed by the Colorado Department of Public Health and Environment (CDPHE) with the goal of developing a protocol to characterize built environments and ventilation strategies in Colorado nursing homes during the COVID-19 pandemic. The working group was led by representatives from CDPHE and the Colorado School of Public Health (CSPH) and included stakeholders from multiple Colorado agencies

Table 1. COVID-19 Built Environment Recommendations Issued by the Centers for Disease Control and Prevention (CDC) and ASHRAE.

Intervention Category	Recommendation	Organization
Resident isolation	Limit residential units to one resident per space/room	CDC
	Create physically separated COVID unit(s) within care facilities	CDC
	Place newly admitted residents in single occupant rooms/observation areas until they are symptom free for 14 days	CDC
Improved indoor air quality	Keep residents cohorted within a unit, wing, or floor	CDC
	Increase outdoor air ventilation	CDC, ASHRAE
	Improve levels of filtration. Use MERV 13 rated filters, or higher, to help remove viruses from circulated air	CDC, ASHRAE
	Use portable high-efficiency particulate air filtration systems to enhance air cleaning	CDC
	Ensure ventilation systems operate properly	CDC
	Create areas with relative air pressure differences	ASHRAE
Staff separation/support	Maintain 40%–60% humidity	ASHRAE
	Provide spaces for staff PPE donning/doffing	ASHRAE
	Provide areas for staff respite	ASHRAE
	Provide spaces within COVID unit(s) to allow COVID-only staff to isolate from the rest of the facility. Recommended spaces include a staff restroom, a break room, and a work area.	CDC

Note. MERV = minimum efficiency reporting value.

and partner organizations, including organizations that own/operate nursing homes in the state.

Representatives from the CSPH, in collaboration with the working group, developed the Nursing Home Built Environment (NHBE) survey tool to facilitate the collection of data needed to develop a comprehensive characterization of the built environments of Colorado NHs during the COVID-19 pandemic (**Table 2**). The working group that developed the survey included Colorado nursing home representatives who worked either in operations or in maintenance of their facilities. Prior to the launch of the survey, it was pilot tested with three nursing home organizations that have multiple facilities in Colorado. Respondents to the pilot survey were asked to provide feedback related to each section of the survey. All comments were assessed by the survey development team, and questions that caused confusion for the respondents were modified prior to the launch of the survey.

The NHBE Survey was developed in three parts using the RedCap online survey platform: (1) Main Point of Contact (MPC) Survey, (2)

Operations Survey, and (3) Facilities Survey. The goal of creating the survey in multiple parts was to obtain information about the various components of the nursing homes from representatives that were most knowledgeable about the specific aspects of the design and operation of the buildings, to minimize the collection of inaccurate information due to a lack of knowledge of the respondents as much as possible. To this end, questions related to general property information (name, address, etc.) and ownership were asked in the *MPC Survey* which was typically completed by nursing home organization leaders; questions related to daily function of the NHs (daily occupants, types of care, etc.) were included in the *Operations Survey*, which was typically completed by NH managers, and questions related to building characteristics (size, age, etc.) and heating, ventilation, and air conditioning (HVAC) systems were included in the *Facilities Survey*, which was typically completed by maintenance managers (**Table 3**). None of the survey sections requested personal health information from respondents. The NHBE survey tool was

Table 2. Definitions for Built Environment Terms.

Concept	Definition
Built environment	Man-made structures, features, and facilities viewed collectively as an environment in which people live and work.
Nursing home (NH)	A residential facility that provides frail elderly and people with chronic illness routine or skilled nursing care.
Long Term Care Facility (LTCF)	Facilities that provide a variety of services, both medical and personal care, to people who are unable to live independently. LTCF include NHs, skilled nursing facilities, and assisted living facilities.
Cohorting	The practice of isolating multiple individuals together as a group. Used as a harm reduction strategy to minimize the risk of disease spread and adverse health outcomes.
Residential unit (RU)	A dwelling space within a NH. An RU is typically occupied by one to four residents. RUs may be similar to an apartment and have a kitchen, seating area, and/or a dedicated bathroom. They may also be a sleeping space with no additional functionality.
Common areas	Areas used for people to congregate for social activities, especially people who live together.
Neighborhood	A group of rooms that serve a designated population. The group of rooms may consist of RUs only, or it may include accessory spaces serving that specific area (kitchen, lounge, etc.). Other terms used include “Wings,” “Halls,” “Villages,” and “Pods.”
Heating, ventilation and air conditioning system (HVAC)	The equipment (furnaces, condensing units, etc.), distribution systems (ducts, pipes, etc.), and controls (thermostats, building automation systems, etc.) that create a system that generates and distributes heating, ventilating, and/or air conditioning to a building or portion of a building.
MERV Rating	The Minimum Efficiency Reporting Values rating reflects a filter’s ability to capture particles between 0.3 and 10 microns (μm). The higher the MERV rating, the better the filter is at trapping smaller particles.
Portable HEPA air purifier	A stand-alone device used to remove particulate matter from the air using a high-efficiency particulate air (HEPA) filter. According to the CDC, HEPA filters are no less than 99.97% efficient at capturing human-generated viral particles associated with SARS-CoV-2.
Decontamination area/ clean room	An area/room that is constructed/operated in a way that controls the introduction, generation, and retention of contaminants inside the space.
Airborne infection isolation room	A single-occupancy residential space/room used to isolate persons with airborne infectious disease. Also referred to as a “negative pressure room.”

Source: www.ashrae.org, www.cdc.gov, www.nih.gov, www.epa.gov, www.iso.org, languages.oup.com

reviewed by the Colorado Multiple Institutional Review Board and was determined to be “Not Human Subject Research.” IRB # 20-2496.

Access to the NHBE survey was provided to all 225 licensed nursing homes in Colorado using an electronic distribution list held by CDPHE. Communications included a request that organizations which own or operate NH properties in Colorado voluntarily complete surveys for all of their Colorado NH facilities. No incentives were provided to those entities that completed the surveys. The NHBE survey was launched October

20, 2020, and closed November 20, 2020. At the time that the study was conducted, all Colorado nursing homes were required to restrict visitation and use personal protective equipment per State Public Health Order 20-20.

Results

MPC Surveys were completed for 121 (55%) of the NH properties in Colorado, Operations Surveys were completed for 78 (35%) properties, and Facilities Surveys were completed for 69 (31%)

Table 3. Sample Nursing Home Built Environment Survey Questions.

Survey	Questions	Response Options
Operations	What types of residential units are provided at your property?	Single occupancy, double occupancy, triple occupancy, quadruple occupancy, other
Operations	Which of the following are provided in a typical (single occupancy, double occupancy, triple occupancy, quadruple occupancy) RU? Which of the following are provided within the boundary of each neighborhood? What STAFF accommodations are provided within the boundary of each neighborhood?	Kitchen/kitchenette area, living room/seating area, private bathroom, semi-private bathroom (shared with one other RU), washing machine and clothes drier in RU, direct access to an outdoor patio/balcony area, windows that can be opened for fresh air, none of the above Skilled nursing, long-term care, memory care, other secure care, COVID-19 positive care, quarantine/watch, specific nationalities/language speakers, gender specific Dining room, gathering spaces kitchen, laundry room, outdoor patio area, therapy bathing rooms, therapy rooms, treatment rooms, nurse station, other Break room, locker room, decontamination room, hand washing station(s), staff bathrooms, outdoor patio area, sleeping rooms, office space, other, none of the above Before 1950, 1951–1979, 1980–1995, 1996–2005, 2006–2016, 2017–present 1, 2, 3, 4, 5 Common areas, residential units, common areas and residential units
Facilities	Which date range includes the original year of construction of the facility?	Filters with a minimum efficiency reporting value (MERV) rating of 1–6, filters with a MERV rating of 7–12, filters with a MERV rating of 13–16, filters with a MERV rating of 17–20, high efficiency particulate air filters, high efficiency gas absorption filters, no filters used, don't know, other
Facilities	How many different (HVAC) system TYPES does your facility have?	Portable air cleaners, ultraviolet (UV) light (return air), UV light (supply air), bipolar ionization, photohydro-ionization, other, none of the above, don't know
Facilities	Does (each specific HVAC) system serve common areas, residential units, or both? What is the highest level of filtration media being used by (each specific HVAC) system currently?	No ventilation provided, ducted return air system, operable windows, passive return air system, ducted bathroom vent fans (operated by switch), ducted bathroom vent fans (continuous operation), don't know, other
Facilities	Does (each specific HVAC) system use any of the following enhanced decontamination strategies?	
Facilities	How is ventilation provided for the areas served by (each specific HVAC) system?	

properties. Sixty (27%) NHs completed all portions of the NHBE survey. We feel that the findings are representative of the NHs in Colorado that did not complete the survey because responses were received from geographically diverse areas of the state and are consistent with the percentages of NHs located in the various Colorado counties. Counties with the highest percentage of NHs in Colorado were represented similarly in the survey responses including Denver (CO-10%, Survey-9.8%), Arapahoe (CO-10%, Survey-9.3%), El Paso (CO-8.9%, Survey-9.8%), and Jefferson County (CO-14.4%, Survey-9.8%). Of the 64 counties in Colorado, only 46 have CMS-licensed nursing homes. The NHs in the survey response pool were from 28 (61%) of these counties. Of the 18 counties not represented, 72% had one nursing home located in the county and 22% had two nursing homes located in the county. The size of the facilities in the survey is consistent with those throughout Colorado. Colorado NHs have an average occupancy of 90 residents, while the NHs in the survey response pool have an average of 96 residents, and beds in a single facility ranged from 40 to 210. While the construction dates of all Colorado NHs are not known, the buildings represented in the survey had construction dates that ranged from before 1950 to after 2017, reflecting a variety of built environment conditions that we feel is similar to that of the nursing homes that did not respond to the survey.

Resident Isolation

Resident isolation strategies outlined in the CDC/ASHRAE guidelines were not typically implemented in CO NHs. Forty-five (57%) of the NHs that participated in the study indicated that fewer than a quarter of their resident beds were located in single-occupancy rooms. Seventy-one (91%) of the NHs had not created COVID-positive “neighborhoods” to cohort residents. Of the nine facilities that had created COVID-positive neighborhoods, none had all of the necessary accommodations (dining area, lounge area, staff break room, etc.) within the boundary of the neighborhood to allow for staff/resident cohorting during the pandemic (**Table 4**).

Indoor Air Quality

Indoor air quality strategies included in CDC/ASHRAE guidelines have not been implemented by the majority of Colorado NHs. Increasing outdoor air ventilation using mechanical systems was not possible for most of the NHs because 46 facilities (67%) did not have HVAC systems that provided a way to control the amount (percent) of outside air that was brought into the interior environments for common areas, and 51 (74%) did not have systems with this capability for residential units. Responses to the *Operations Survey* indicate that 68 of the NHs (78%) had operable windows in the RUs which were capable of directly bringing outside air into the spaces during times of good outdoor air quality, while responses to the *Facilities Survey* reported that only 28 of the NHs (41%) were actively using operable windows for ventilation. Filtration media used to “clean” recirculated air within the mechanical systems only met the recommended MERV 13 (or above) levels for common areas in 14 NHs (20%), and for residential units in 13 NHs (19%). Filters were replaced less than once a year for common areas in 20 facilities (29%) and less than once a year for residential units in 23 facilities (33%). Sixty-one facilities (88%) indicated that they were not utilizing any enhanced air decontamination measures, including portable air purifiers. Only six facilities (9%) indicated they had designated negative pressure airborne infection isolation rooms. Humidity levels in indoor spaces could be controlled in one of the NH facilities for the common areas and in none of the facilities for residential spaces (**Table 4**).

Staff Separation/Support

Survey responses show Colorado NHs provided select staff-supportive spaces which were typically located in central locations and were utilized by all facility staff. Seventy-five NHs (96%) indicated they provided break rooms, while less than 50% provided locker rooms, decontamination rooms/areas, or staff sleeping rooms. Only two facilities (3%) had COVID-designated “neighborhoods” that provided CDC-recommended staff support areas that would have

Table 4. Findings Related to CDC and ASHRAE Recommendations.

Category/Recommendation	Built Environment Strategy	Provided in CO NHs	
		Number	Percentage
Resident isolation (n = 78)			
Limit residential units to one resident	100% of NH ^a Beds are in SO ^b RUs ^c	13	17
	50%–99% of NH ^a Beds are in SO ^b RUs ^c	11	14
	25%–49% of NH ^a Beds are in SO ^b RUs ^c	9	12
Cohort residents in a unit, wing, floor	Provide “neighborhoods” for residents	52	67
Create physically separated COVID unit(s) within care facilities	Provide a COVID-positive area that is separated from other populations	7	9
Place newly admitted residents in observation areas for 14 days	Provide a COVID watch area that is separated from other populations	13	17
Improved indoor air quality (n = 69)			
Increase outdoor air ventilation	Use HVAC systems which allow for increased outdoor air intake (CAs) ^d	23	33
	Use HVAC systems which allow for increased outdoor air intake (RUs) ^c	18	26
	Provide operable windows in RUs (n = 78)	68	87
	Use operable windows in RUs for ventilation	28	41
Improve levels of filtration	Use MERV 13+ Filters (CAs) ^d	14	20
	Use MERV 13+ Filters (RUs) ^c	13	19
Ensure ventilation systems operate properly	Replace filters at least annually (CAs) ^d	49	71
	Replace filters at least annually (RUs) ^c	46	67
Create areas with relative air pressure differences	Provide negative pressure airborne infection isolation rooms (AIIRs)	6	9
Use portable high-efficiency particulate air (HEPA) filtration systems to enhance air cleaning	Use enhanced decontamination strategies including portable air cleaners	0	0
Maintain 40%–60% humidity	Use HVAC systems which control the percentage of relative humidity (CAs) ^d	1	1
	Use HVAC systems which control the percentage of relative humidity (RUs) ^c	0	0
Staff separation/support (n = 78)			
Provide spaces for staff PPE donning/doffing	Locker rooms w/o showers	34	44
	Locker rooms with showers	14	18
	Decontamination rooms	13	17
Provide areas for staff respite	Interior break rooms for staff	75	96
	Exterior break areas for staff	40	51
	Sleeping rooms for staff	12	15
	Lactation rooms for staff	26	33
Provide spaces within COVID unit(s) to allow COVID-only staff to isolate from the rest of the facility. Recommended spaces include a staff restroom, a break room, and a work area	NHs with a COVID “neighborhood” with a dedicated staff break area	3	4
	NHs with a COVID “neighborhood” with a dedicated staff restroom	6	8
	NHs with a COVID “neighborhood” with a dedicated staff work area	2	3

^aNursing Homes.^bSingle Occupancy.^cResidential Units.^dCommon Areas.

allowed staff to cohort separately and still have their needs met related to delivering adequate care to residents and supporting their own mental and physical health (**Table 4**).

Discussion

Our study found relatively few Colorado nursing homes adopted the CDC/ASHRAE COVID-19 recommendations related to resident isolation, improved indoor air quality, or staff separation/support during the pandemic (ASHRAE, n.d.; CDC, 2021b, 2022; Stuart, 2020). While we found that many of the existing built environments of the nursing homes in our study are faced with significant challenges associated with modifying their systems and spaces to support resident and staff health, there is still a need to consider what actions are possible in the near term to address the continued spread of COVID-19 and other infectious diseases.

In order to support the mental and physical health of nursing home residents, isolation for infection control must include *both* private living spaces for occupants *and* access to communal gathering spaces that can adapt when cohorting is necessary (Anderson et al., 2020; Kane et al., 2007). With typical Colorado nursing homes having less than a quarter of their beds located in single-occupancy dwelling units, residents do not have the ability to fully isolate themselves to mitigate the spread of illness. The arrangement of residential units into small home-like communities or “neighborhoods” is a design/operation strategy that has the potential to meet the daily needs of residents and staff as well as be adaptable to allow for cohorting. Cohorting of residents and staff is a viable strategy to lower the levels of morbidity and mortality in NHs resulting from infectious disease outbreaks including COVID-19, influenza, and norovirus (Belmin et al., 2020; Krone et al., 2021; Zimmerman et al., 2021). While neighborhoods (pods, wings, floors, etc.) serving specific populations are not a new concept, they are not typically designed or operated in a manner that allows them to function separately from the main facility (Schwarz & Brent, 2001). More than 50% of Colorado NHs in our study indicated that they have some or all of their residential units arranged in “neighborhoods,” so there is the opportunity for

existing neighborhoods to be modified to include common spaces that support residents and staff during times of isolation. The isolation of groups of residents and staff in physically separated areas has the potential to limit the spread of disease throughout a facility, when used in combination with other infection prevention strategies.

The ventilation strategies included in the CDC and ASHRAE guidelines typically require centralized ducted heating and air conditioning (HVAC) systems (ASHRAE, n.d.; CDC, 2021b; Stuart, 2020). If existing systems cannot accommodate optimal filtration media (MERV 13 and above) or control the percentage of outdoor air intake, alternative measures like the use of CDC-recommended HEPA portable air filtration devices need to be considered. A non-HVAC system opportunity to improve ventilation that was identified in our study was increasing the use of operational windows to introduce fresh air into interior spaces (Escombe et al., 2019; Sharpe et al., 2020). This could be accomplished through operational/policy changes that encourage windows to be opened in common areas and residential units when weather and air quality permits. There are also opportunities for improved air quality by implementing no- or low-cost maintenance practices, including replacing filters according to the manufacturer’s recommendations and testing and balancing HVAC systems to assure they are functioning as designed (CDC, 2021b).

Staff separation/support spaces are needed during times of normal operation, not just during a pandemic. Spaces that promote the physical and mental health of nursing home staff are linked to lower staff turnover and improved infection control (Fan et al., 2020; Nejati et al., 2016; Pricewaterhouse Cooper, 2004; Rechel et al., 2009), both of which are ongoing concerns. While most Colorado NHs in our study have staff break rooms, less than 50% provide locker rooms, decontamination rooms/areas, or staff sleeping rooms, indicating that staff needs related to the built environment are not currently being met in typical nursing home facilities.

Staff separation/support spaces are needed during times of normal operation, not just during a pandemic.

Only two (3%) of the NHs surveyed have staff accommodations located within a residential neighborhood to allow for cohorting of residents and staff during disease outbreaks. Built environment and ventilation improvements are likely to require repurposing of existing spaces, substantial modifications to HVAC systems, and changes to operational practices. Barriers to making changes to nursing home buildings include inadequate funding for renovations and less income potential if multi-occupant residential units are converted to single occupant units (“Pre-COVID: Medicaid’s Chronic Underfunding Had Already Forced Hundreds of Nursing Homes to Close,” 2020). Based on the survey findings, we feel that nursing homes will need to use a tiered approach when seeking to improve their built environments. Initially, they can make low-cost improvements including using higher levels of filtration when possible, replacing filters according to manufacturers’ recommendations, and using operable windows for improved ventilation when weather/air quality permits. Nursing homes can then implement health-promoting built environment upgrades when routine capital improvement work is required due to the age or condition of an existing facility and/or system. This is expected to mitigate the financial burden to the NHs as capital improvements should already be integrated into their capital needs budgets, and the upgrades may only result in a relatively modest budget increase. Finally, when new nursing home facilities are constructed, designers and stakeholders (owners, operators, facilities staff, resident groups) need to work collaboratively to assure the environments of new facilities support the physical *and* mental health of *all* building occupants. To determine the best practices for health-supportive nursing home design, it will be the responsibility of design teams to thoughtfully integrate innovative nursing home design practices that were emerging prior to the pandemic (Cohen et al., 2016; Wrublowsky, 2018) with the CDC and ASHRAE strategies recommended during the pandemic.

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Strengths and Limitations

The strengths of our study are that it characterizes the built environments and ventilation systems of nursing homes which have not been accomplished by other studies, and it provides a rare look into the adoption of recommended built environment infection control strategies during the COVID pandemic. Our study has several limitations. Facilities self-reported survey data, and we were not able to verify the validity of survey responses through site visits to NHs due to COVID-related visitor restrictions. Therefore, the potential for information bias due to self-report exists. There is also the potential for selection bias as nursing home facilities opted-in to take the NHBE survey. It is possible that respondents were more likely to have complied with CDC/ASHRAE recommendations than nonrespondents, and that the percentage of Colorado facilities that instituted the recommendations is lower than our finding indicate. The NHBE survey only collected information on Colorado nursing homes, so our findings may not be generalizable to other states/countries due to location-specific built environment considerations.

Conclusion

Our study found that very few Colorado nursing homes adopted the CDC and ASHRAE COVID-19 built environment recommendations related to resident isolation, improved indoor air quality, and staff separation/support. This finding is important because the CDC and ASHRAE recommendations are relevant at *all times* for nursing home facilities, not just during the COVID-19 pandemic, because the vulnerable populations who occupy the built environments of these residential care facilities are disproportionately impacted by infectious viral illnesses including influenza and norovirus. The low level of adoption of built environment infection control strategies indicates that existing Colorado nursing home facilities have significant barriers to implementing fundamental health-protective measures which likely include HVAC system and physical space limitations as well as a lack of financial resources that are needed to create substantial

changes to their built environments. For this reason, we propose that nursing home properties use a three-tiered approach to making upgrades, starting with low-cost improvements in the near term to address the immediate health needs of building occupants as quickly as possible, prioritizing more costly upgrades when routine capital needs work is done, and implementing substantial built environment improvements when new facilities are constructed. As we continue to respond to the COVID-19 pandemic and we reassess the importance of built environments for health protection and health promotion, it is critical that organizations that own/operate nursing homes and nursing home designers work together to improve the built environments of nursing home facilities to support the mental and physical health of residents and staff.

Implications for Practice

- The design and operation of existing nursing homes do not support the health of residents and staff during infectious disease outbreaks.
- Existing nursing homes need to critically look at their built environments and ventilation systems to target capital improvements that will support the health of building occupants.
- Architects that design nursing homes in the future need to look at their design strategies through the lens of public health and focus on providing functional, adaptive, health-supportive environments.

Authors' Note

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