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Review of the Impact of Housing Quality on Inequalities in Health and Well-Being

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Abstract

Housing quality is essential for population health and broader well-being. The World Health Organization Housing and health guidelines highlight interventions that protect occupants from cold and hot temperatures, injuries, and other hazards. The COVID-19 pandemic has emphasized the importance of ventilation standards. Housing standards are unevenly developed, implemented, and monitored globally, despite robust research demonstrating that retrofitting existing houses and constructing high-quality new ones can reduce respiratory, cardiovascular, and infectious diseases. Indigenous peoples, ethnic minorities, and people with low incomes face cumulative disadvantages that are exacerbated by poor-quality housing. These can be partially ameliorated by community-based programs to improve housing quality, particularly for children and older people, who are hospitalized more often for housing-related illnesses. There is renewed interest among policy makers and researchers in the health and well-being of people in public and subsidized housing, who are disproportionately disadvantaged by avoidable housing-related diseases and injuries. Improving the overall quality of new and existing housing and neighborhoods has multiple cobenefits, including reducing carbon emissions.

INTRODUCTION

In high-income countries, we spend most of our time inside our houses (6), and the quality of the construction largely locks in carbon emissions for decades (166). The importance of our houses to our health and well-being is highlighted by the disruptive impacts of major economic changes, such as industrialization (144); environmental events, including flooding and fires (35); and political changes, such as invasions (165). These disruptions often drive people to leave their homes and neighborhoods to crowd together in unhealthy, poorly ventilated temporary homes in precarious settlements, with major impacts on their health and well-being (152).

The nineteenth-century sanitary and housing reforms, led by European and US public health reformers, highlighted the extent of the burden of infectious diseases on those who had little economic choice but to live in crowded tenements and slums (139). The reformers' prolonged endeavors led to the recognition by the public and politicians that housing was a key social and environmental determinant of health (151). Public housing became a focus for governments and philanthropists addressing the needs of the urban poor. After the Great Depression and WWII, both local and national governments undertook major public housing programs and encouraged the private development of large-scale suburban housing developments.

In the twenty-first century, suburban development has continued; however, inner-city intensification is accelerating, while political support for maintaining affordable and public housing has been waning (14). Housing shortages are becoming increasingly widespread. Deferred maintenance of housing and sanitary infrastructure, often more than a century old, requires urgent remediation and renewal to maintain occupants' health (78). Adding to this urgency is the impact of governments' policy responses to the COVID-19 pandemic (65) and climate change. The COVID stay-at-home orders, or lockdowns, heightened recognition of the importance of indoor ventilation and how household crowding can spread infectious diseases. A focus on reducing carbon emissions, through building construction and operation, is firmly on the policy agenda. As the United Nations Sustainable Development Goals (SDGs) highlight, health is influenced by many systemic factors, including climate change; action is needed to increase the density and connectedness of urban and suburban areas and to increase active, public, and shared transport within and between them (70, 113).

AIMS

This review concentrates on growing evidence about effective system interventions to improve the quality of housing and neighborhoods for equity and for health and well-being outcomes (99, 150). Associations between housing and health have been well canvassed in previous reviews (18), and the links to interventions are summarized in **Figure 1**, which describes the social and economic pathways through which the quality of housing either protects health or increases the risk of respiratory, cardiovascular, and infectious diseases.

Here we focus largely on robust evidence from public health interventions in randomized controlled trials (RCTs) and natural experiments (66, 125, 162). We review recent evidence for housing interventions in existing houses, grouping interventions into single fixes, such as retrofitting insulation (45, 67), improving heating (68), and reducing injury hazards (81, 86), followed by whole-house remediations (61, 62, 78). We consider accumulating evidence that building better new housing with more sustainable materials can also significantly mitigate the major planetary health hazard of climate change (54).

Cognizant of the World Health Organization's (WHO) Housing and health guidelines (175), we initially address updated evidence for effective interventions to address the impacts of crowding, injuries, indoor cold and heat, damp and mold, poor indoor air quality, and accessibility on health and well-being outcomes. These outcome measures include occupants' self-reports of

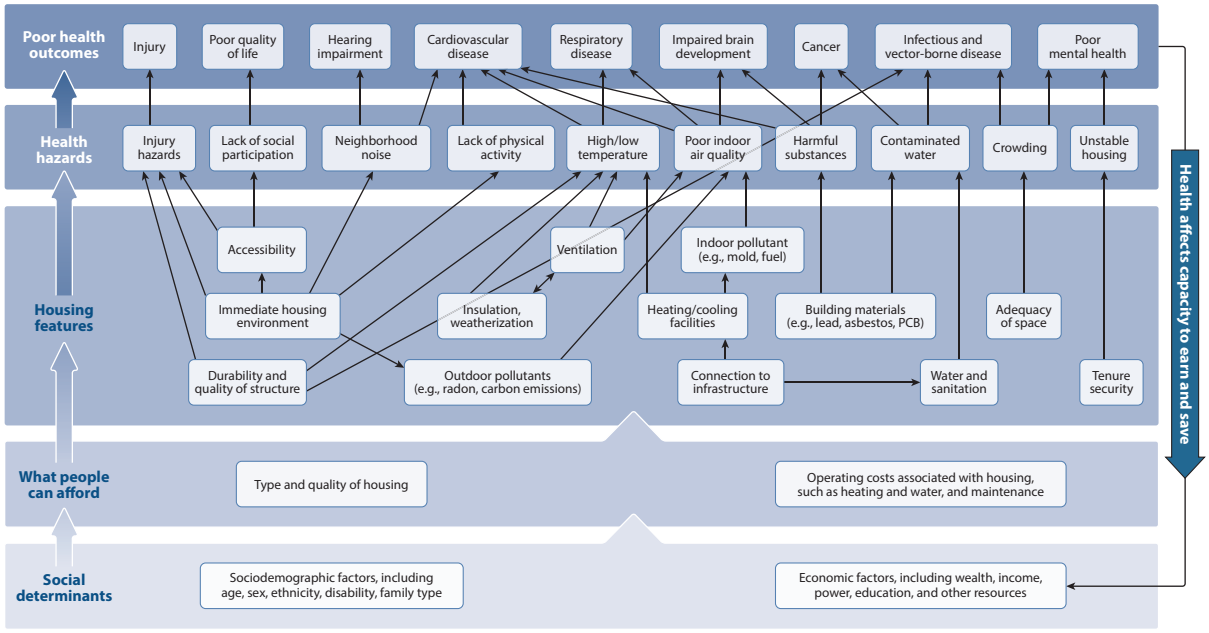

Figure 1

Housing pathways to health. Abbreviation: PCB, polychlorinated biphenyls.

health, independent measures of health care utilization, hospitalization, and broader measures such as days off school and work. We then consider the relative effectiveness of broader, integrated interventions.

The negative impacts of low-quality housing fall inequitably. We highlight the cumulative disadvantages faced by Indigenous peoples, ethnic/racial minority groups, individuals with low incomes, and vulnerable people, particularly when they are tenants. Although we recognize that these populations are more likely to live in housing that lacks basic amenities (1) or to experience homelessness, these circumstances are beyond the scope of this review.

There is growing recognition by researchers and governments that improving housing is a systemic issue, which requires policy changes at multiple levels from the global to the local (65). Evidence-based policy recommendations need to be developed, adopted, piloted as policy, implemented in different jurisdictions, evaluated, and then upscaled. Building on earlier reviews (15, 48, 78), we consider whether current approaches to intervention, including existing guidelines and regulations, will improve health and well-being (69, 158).

HOUSING QUALITY INTERVENTIONS FOR HEALTH AND WELL-BEING

Housing is a critical social, cultural, and environmental determinant of health and well-being (82, 83). In 2009, a systematic Campbell review on housing interventions mapped and evaluated specific housing interventions that could improve health (162). For example, community health workers successfully intervened in inner-city households to reduce triggers for asthma such as cockroach allergens, dust mites, and environmental tobacco smoke (106). Takaro and colleagues (156) found that combining such interventions with "asthma-friendly" home modifications was effective in preventing asthma symptoms and in reducing days away from school and work and

visits to hospitals. In the United States, a Department of Housing and Urban Development program expanded lead control efforts from lead paint mitigation to contaminated dust and soil and remediation of other health effects in housing (75, 77).

Temperature and Respiratory and Cardiovascular Disease

Excess winter mortality occurs when housing inadequately protects occupants from low winter temperatures. Research showing that people are more likely to die from respiratory and cardiovascular diseases during winter in temperate rather than colder climates (25) has shifted research and policy focus to the combined effects of poor-quality housing, inadequate insulation, and low incomes linked to fuel poverty (10). The impact of minimal (or no) heating and insulation contributes to low indoor winter temperatures, which clearly exacerbate cardiovascular and respiratory conditions in Europe (37), the United Kingdom (9, 10, 26, 111, 120), and New Zealand (27, 100, 116, 117, 160, 169). In the United States, fuel poverty, despite its prevalence in one-third of households, has not been formally recognized by the federal government (7), although energy costs are subsidized to some extent at federal, state, and local levels.

Energy costs are rising, and in temperate climates houses are not always heated, particularly children's bedrooms (153). Inadequately heated houses are more likely to be damp, which can lead to the growth of mold (121); independent of temperature, mold causes respiratory difficulties (72). Even in US homes with central heating, poorly designed ventilation systems have been linked to idiopathic pulmonary hemorrhage (90) and fatalities (30). Several studies, including a NZ case-control study of children living in cold, damp houses, have found that these children were more likely to be hospitalized for acute respiratory conditions (71). In addition, children who had been admitted to the hospital were more likely to be readmitted (119).

These descriptive studies indicate that low indoor temperatures cause illness and deaths, particularly among vulnerable young and older people, but focus less on preventive public health and housing action. After the 1970s oil shock, the International Energy Agency focused on the demonstrable cobenefits of improving thermal efficiency in older housing (145). Associated initiatives included the US Weatherization Assistance and Low-Income Home Energy Assistance programs (7); the English Warm Front Program (49, 55); and the NZ Warmer Kiwi Program (63). The NZ program was augured by the Housing, Insulation and Health Study, a clustered intervention RCT conducted in 2001–2002 on the impact of retrofitted insulation in 1,350 households, which resulted in a significant increase in indoor temperatures and a decrease in humidity in the insulated houses, as well as savings in energy consumption relative to control houses. These indoor environment changes were sufficient to significantly improve the occupants' self-reported health and wheezing and reduce visits to doctors, days off work, and children's days off school (67). Although a reduction in hospitalizations was not statistically significant, a cost–benefit analysis found that benefits exceeded costs by a ratio of 1.8:1 (21).

As the average indoor temperature in the houses in the Housing Insulation and Health Study did not reach the WHO-recommended 18°C (64°F), this study was followed by another RCT conducted in 2005–2006, the Housing, Heating and Health Study, which involved replacing unsafe, portable unflued gas heaters in the homes of 409 children with asthma (68). Because these gas heaters release nitrogen dioxide (NO_2) and other combustion by-products, they were replaced with the householder's choice of a more efficient and effective heater: a flued gas heater, an electric heat pump, or a wood-pellet stove (12). Homes in the intervention group subsequently had significantly lower levels of NO_2 in both living areas and children's bedrooms (52). Measurements of daily lung function and hourly indoor temperature showed that higher indoor temperatures and reduced levels of NO_2 had a small, but significant positive association, with short-term variations in the lung function of children with asthma, who suffered greater upper and lower respiratory

symptoms and used reliever medication more frequently (51, 127). Independently measured school absences were reduced by 21% (42). However, the cost–benefit analysis, focusing solely on the benefits to the child with asthma, showed only marginal benefits over costs (1.09:1) (133).

The Warm-up NZ Program was rolled out nationally in 2009. Government investment in this combined insulation and heating scheme was based on the demonstrable health benefits (67, 68) and the estimates of cost-effectiveness in terms of morbidity and mortality prevented, compared with the costs of remediations (22). This program has been evaluated twice, first in a quasi-experimental, subcohort study using an administrative sample of ~900,000 people. This study looked at the mortality risk of older members of the cohort, who had prior cardiovascular or respiratory hospitalizations, compared with a matched control group that had not received the combined insulation and heating. The study found a significant protective effect from the retrofitted insulation for those with existing circulatory conditions, accompanied by an improvement in energy use; but no significant changes were found for the addition of a heating intervention (134). A second quasi-experimental evaluation used a retrospective cohort design and compared changes in hospital admissions for intervention and control groups from 2009 to 2014 (45). Admission rates were significantly lower in the intervention population. Postintervention, lower hospital admission rates were found among Pacific peoples and for people over 65 years of age for asthma, cardiovascular disease, and ischemic heart disease. There was also a 4% reduction in pharmaceuticals for treating respiratory exacerbations in the intervention group, but not enough to eliminate the need for asthma prevention medication (44).

With stronger evidence for the effectiveness of retrofitting insulation than for a heater, which could remain unused due to energy costs, studies in the United Kingdom (122, 123) and New Zealand (169) have explored using heating vouchers to reduce fuel poverty in vulnerable households. However, a recent UK House of Commons report highlighted definitional issues, such as assuming that all households that received vouchers were no longer in fuel poverty, which makes monitoring policy effectiveness problematic (58). In 2017, the NZ government introduced the Winter Energy Payment with differential rates for people over 65 years and welfare beneficiaries (115). To evaluate the effectiveness of this policy, people over 55 years with doctor-diagnosed chronic obstructive pulmonary disease (COPD) were recruited into the staggered intervention trial Warm Homes for Elder New Zealanders Study, conducted from 2009 to 2013, during which participants' houses were insulated and families received an electricity voucher. The primary outcome investigated was respiratory exacerbations requiring treatment with antibiotics and/or corticosteroids. Participants assigned to the first intervention group showed no significant health gain, although secondary analyses suggested a lower mortality rate among participants assigned to the intervention group (169).

Cold houses increase damp and mold, which accounts for a substantial proportion of the burden of respiratory disease (138). Two NZ intervention studies have focused on the vulnerability of children exposed to cold bedrooms. The Health of Occupants of Mouldy Environments (HOME) study conducted in 2010–2012 was an incident case-control study involving 150 children, aged between 1 and 7 years, with new-onset wheeze, each of whom was matched to two control children with no history of wheezing. Children were tested for aeroallergens to establish atopy. Repeated measures of temperature and relative humidity were taken (153); the presence and type of airborne microbes were collected on electrostatic dust cloths and analyzed by quantitative polymerase chain reaction in Finland, but neither temperature, nor relative humidity, nor microbes were associated with new-onset wheezing (80). Each child's home was assessed for moisture damage, condensation, and mold growth by researchers, independent building assessors, and parents. Study investigators found strong positive associations between observations of visible mold and new-onset wheezing in children in a dose-dependent manner. The association between mold and new-onset

wheeze was not modified by the children's atopic status, suggesting a nonallergic association (154). The Nest Study conducted between 2016 and 2022 is a primary prevention study focused on babies; it aims to protect newborn infants from being hospitalized for respiratory symptoms by heating infants' rooms and providing babies with sleep sacks to keep them at a constant temperature and is currently being analyzed.

ADDRESSING CLIMATE CHANGE AND AIR QUALITY

In the built environment, carbon emitted in housing construction (embodied) as well as emissions from household energy use are significant contributors to climate change (73). They can be mitigated through higher building and energy efficiency standards (54), which can also provide health cobenefits (166, 174). Besides mitigation, the increasing acceleration of climate change makes it clear that new houses being built, and existing houses being remediated, need to explicitly factor in protecting occupants from extreme temperatures: more intense, prolonged heat waves, as well as increasing periods of intense, cold weather in some areas. While there is strong evidence about the health impacts of cold temperatures, there is less evidence about the impact of indoor rather than outdoor heat. Systematic reviews that underpin the WHO guidelines concluded that there is strong research evidence that building to higher insulation standards is effective in reducing the respiratory and cardiovascular effects of cold housing (175). Although it is clear from the growing death toll from heat waves that heat can kill, we lack empirical data of studies with concurrent indoor and outdoor temperatures; therefore, the guidelines on heat are based on modeling. This lack of data is an important gap in our public health knowledge.

In a systematic review of articles to identify the potential health cobenefits of green building strategies between 2002 and 2012, the authors focus on community resilience to extreme heat and marshal compelling evidence of the potential impact of cross-sectoral collaboration among public health departments and their partners in the housing, planning, emergency, and transportation sectors (60). Significant factors that reduced heat were the selection of sustainable sites that reduced urban sprawl and the heat island effect and, in terms of health cobenefits, increased indoor air quality and opportunities to exercise.

Indoor Air Quality, Ventilation, Pollutants, and Infectious Diseases

The WHO has provided extensive evidence-based practical guidance to prevent the spread of infections for patients and health care workers. However, while much of this guidance focuses on hand hygiene and personal protective equipment, a WHO 2007 guideline considered adequate natural ventilation to be one of the most effective measures to reduce the spread of infection (173). Although homes do not present the same infection risks as acute care facilities, they still present challenges. Crowding (53), the quality of indoor air, inadequate potable water, and lack of access to adequate plumbing and sanitation have all been identified as household factors that contribute to the burden of infectious diseases. A review of 360 studies investigating housing risk factors for respiratory disease reported that poor indoor air quality, mainly due to a lack of adequate ventilation, was the most influential risk factor (172).

Good ventilation is beneficial in preventing infectious disease transmission, and it can also reduce indoor moisture and concentrations of toxic indoor air pollutants (167). According to the US Environmental Protection Agency, indoor air pollutant levels are typically 2–5 times higher than outdoor levels and, in some cases, can exceed outdoor levels of the same pollutants by 100 times (167). Toxic chemicals produced by the combustion of fuels have a profound effect on people's health; in 2020, ~3.2 million people died prematurely, including 237,000 children under age five, due to illnesses attributable to household air pollution (178). A recent systematic review reported

that women who were exposed to household air pollution during pregnancy had a higher risk of still and preterm birth and infants of low birthweight or who were small for gestational age (180).

Until recently, air quality research has tended to consider primarily outdoor air quality, and the main indoor air quality focus has been the predominance of low- and middle-income households who use biomass for cooking. The latter is a key public health issue globally and was ranked as the seventh largest contributing risk factor in the Global Burden of Disease study (40, 132). For example, a recent study explored the impact of household biomass use on children under age five in Ethiopia and reported that children who were physically close to polluting energy sources during cooking were at significant risk of developing acute respiratory infections. The study authors strongly recommended that policies and regulations enacted should address the barriers that impede the development of clean and efficient energy sources (2). Cooking over open fires also increases the risk of burns, particularly for children (157). Improving indoor air quality through household ventilation would result in a reduction in multiple adverse health outcomes, including respiratory illness (33), allergic symptoms, cancers, and premature mortality (168).

Another indoor air quality issue is exposure to secondhand smoke (SHS) from tobacco smoking, which is associated with multiple adverse health effects, including lung cancer and heart disease, and a range of adverse effects in children (16, 118, 135) and causes an estimated 800,000 deaths each year (148). There is no safe level of SHS exposure, so the most effective way to protect health is to create completely smoke-free environments, particularly in indoor spaces. Globally, exposure to SHS is greatest in low- and middle-income countries, particularly among women and children (148). Public health action has focused on introducing smoke-free policies in public places and workplaces, and about one-quarter of the world's population lives in countries where comprehensive smoke-free policies have been implemented (177). These policies have resulted in reduced SHS exposure and measurable health gains (41).

Exposure to SHS in homes is a major public health issue. Smoking in homes results in sustained high levels of particulate and gaseous pollution and is an increasingly important source of SHS exposure, particularly for children (147–149), with a point of times estimate, based on the latest available survey in each country, of 430 million people estimated to be exposed in China, India, Bangladesh, Indonesia, and the Philippines alone (101). Smoking within individual homes can impact even on smoke-free homes within multiunit housing complexes because SHS pollution drifts or can be distributed through common heating and ventilation systems (155).

There are legal, ethical, and practical challenges and barriers to implementing policy approaches such as prohibiting smoking in homes, although it is more feasible in multiunit housing complexes (155). Another possible approach is through implementing broader smoke-free laws and policies addressing indoor workplaces and public spaces. Despite fears that these would result in displacement of smoking to the home, most studies have found that they either have a neutral effect or, more often, reduce SHS exposure in homes (107). This finding is presumably due to policy implementation changing norms about the acceptability of smoking around other people. Comprehensive tobacco control policies are also associated with an increase in smoke-free homes (independent of effects on smoking prevalence) (39). A range of individual or family-centered health promotion interventions have been implemented that aim to encourage smoke-free homes, often including smoking cessation interventions for parents, although these have generally had limited effect (114, 181). The way forward is likely to be through a combination of comprehensive workplace and public place (including the common areas in multiunit housing complexes) smoke-free policies as well as public education and health promotion campaigns that include encouragement and practical advice for implementing smoke-free homes (148). The effectiveness of these measures will be enhanced by the implementation of comprehensive tobacco control strategies to rapidly reduce and eventually eliminate tobacco smoking, as has recently been proposed in New Zealand (103).

The Impact of COVID-19

The arrival of the COVID-19 pandemic has seen a greater focus placed by health agencies and governments on the importance of good indoor air quality (105). In March 2021, the WHO published a road map to ensure good indoor ventilation in the context of COVID-19 (176), although it had recognized healthy indoor air as a basic human right since 2009, with the quality of the air people breathe indoors being an important determinant of health and well-being (179).

Indoors, infectious airborne viral particles can accumulate, putting everyone in the room at risk of infection, unless indoor air is continuously replaced with outdoor air (36). Lack of ventilation in homes has been shown to contribute to the transmission of tuberculosis (TB) (5); maintaining adequate indoor ventilation can effectively control TB outbreaks (34). Like COVID-19, TB is an airborne disease spread through infectious aerosols generated by infected people (140); for example, transmission risk was higher in South African homes with poor ventilation (98). Similarly, within-household COVID-19 transmission is greater in poorly ventilated homes, the outcome of which has been higher death rates, particularly in lower socioeconomic areas (163). The impact that household crowding with poor ventilation has had on COVID-19 transmission was observed in the escalation of COVID-19 cases among low-skilled migrant workers living in dormitories in Singapore (91). At the time, these infected workers made up 94% of Singapore's confirmed COVID-19 cases (91).

COVID-19 has amplified existing inequalities linked to housing in both developed and developing countries (65). In the United States, the COVID-19 recovery stimulus has created varying economic impacts. Along with a housing boom for those with discretionary income, millions of people, particularly in the informal economy, have lost income or jobs, are behind in rent or mortgage payments, and are more at risk of eviction or foreclosure (79). The United States, United Kingdom, and many other jurisdictions introduced eviction moratoriums (63). A US study in 2021 showed that when the eviction moratoriums established during COVID-19 were subsequently lifted, the incidence of infections and mortality steadily increased. This outcome was probably due to increasing crowding and individuals' decreased ability to socially distance (95). During COVID-19, some evidence has also indicated a trend for families to buy their first home in the suburbs, as these homes were seen to have more space, both inside and outside, which would presumably make working from home easier (94). This trend was amplified when it became evident that the COVID-19 virus was largely airborne (105) and that socializing outside was safer than inside.

Injuries and Disabilities

Globally, one-third of injuries occur in the home (164), and, in 2019, half of all unintentional injury-related deaths occurred in the home (112). Household risks for injuries are highlighted in the WHO Housing and health guidelines as one of the key factors for protecting public health, particularly for people with disabilities. A two-year RCT in the United States showed that injury hazards were significantly reduced in intervention homes but not in control homes, and investigators found a significant 70% reduction in the rate of modifiable medically attended injuries in intervention children compared with controls: 2.3 injuries versus 7.7 injuries per 100 child-years (126). A Canadian case-control study found an increased risk of burns and scalds in children if their house did not have a smoke alarm (93). A large Cochrane review showed that safety education was effective in encouraging the use of safe hot tap water temperatures [odds ratio (OR) 1.35, 95% confidence interval (CI) 1.01 to 1.80], working smoke alarms (OR 1.85, 95% CI 1.24 to 2.75), fitted stair gates (1.26, 95% CI 1.05 to 1.51), and electrical socket covers on unused sockets (OR 3.73, 95% CI 1.48 to 9.39) and the storage of medicines and cleaning

products (OR 1.58, 95% CI 1.18 to 2.13) (OR 1.63, 95% CI 1.22 to 2.17) and sharp objects (OR 1.52, 95% CI 1.01 to 2.29), respectively, out of children's reach (89).

In New Zealand, high rates of home injury correspond with a high prevalence of housing hazards, indicating that addressing safety is a likely pathway to reducing injury rates (85). The Home Injury Prevention Intervention (HIPI) RCT, conducted over 2009–2013, studied rates of falls for occupants in 840 homes (86). Half of these homes were randomized to receive modifications, such as handrails for outside steps and internal stairs and grab rails for bathrooms. Control homes received the same modifications at the end of the trial. There was a 26% reduction in the rate of injuries caused by falls in the treatment group compared to the controls, and injuries specific to the home-modification intervention were cut by 39%. An economic analysis of this intervention found that the costs of home fall injuries fell by 33%, indicating that the more expensive/severe injuries were likely to have been prevented to a greater extent than more minor injuries. The social benefits of injuries prevented were estimated to be at least six times the costs of the intervention. This benefit–cost ratio could be at least doubled for older people and increased by 60% for those with a prior history of fall injuries (irrespective of age).

To examine the health equity implications of the lack of housing stock safety, a further trial of homes with Indigenous Māori occupants was carried out from 2013 to 2017 (87). The rate of fall injuries was reduced by 31% in the modified homes compared with households in the control group. Because Māori households are, on average, larger than non-Māori households, the intervention cost of each fall injury prevented was only around two-thirds of that for the previous HIPI intervention, indicating even greater cost-effectiveness and an even greater potential to reduce injury for Māori.

WHOLE-HOUSE INTERVENTIONS

Housing standards vary from country to country because of different climates, geography, culture, wealth, and housing stock. Whole-house interventions, rather than single interventions, are often determined by the country's legislative framework. Despite evidence on aspects of frameworks, the overall effectiveness of guidelines (69), building codes, and national regulations in improving health and well-being is not clearly established and remains an important research area (170). Government involvement in creating and enforcing housing standards can raise the cost of providing housing, which can affect the affordability of housing for lower-income households but also reduces health service costs, promotes equity, and maintains housing market sustainability. Enforcing legislation, particularly with regard to rental housing, often lacks adequate scrutiny from planning and building control agencies, particularly for low-income households with significant social deprivation (150).

In 2006, in England and Wales, the Housing Health and Safety Rating System (HHSRS) became legally applicable to all dwellings and enforceable in all cases, other than for dwellings owned by the enforcing local authorities (61, 62). The HHSRS shifted the focus from building defects and deficiencies to 29 named threats to health and/or safety, recognizing that dwellings should be free of unnecessary hazards and that any necessary hazards (stairs and steps, electricity) should be as safe as possible. It highlighted that unhealthy dwellings not only have a negative impact on physical, mental, and social well-being, but also interfere with occupiers' feelings of being "at home," a key aspect of well-being (11). The HHSRS was incorporated into the Decent Homes Standard, an administrative standard applied to all public-sector dwellings and a target for all private rented dwellings (31). Clarification of the landlords' obligations has recently been incorporated into contracts for rental properties (59). Progress in achieving the Decent Homes Standard is regularly reported in the House of Commons. In 2018, a review was commissioned on whether the

HHSRS needed updating and whether minimum standards should be incorporated (104). Of the 24.4 million dwellings in England, in 2019 the English Housing Survey identified that the total percentage of dwellings with unacceptable hazards was 10%; 6% of potential fall hazards were on a given floor level, on stairs, between floor levels, or associated with baths/showers (32).

The HHSRS framework was adapted in New Zealand for rental housing as a voluntary Rental Housing Warrant of Fitness (RWoF) proposal to increase the standards of rental housing. This RWoF was based on the evidence from removing health hazards identified in the RCTs outlined above (8, 23, 50, 129, 158, 159, 170). While it generated considerable policy and public interest, it was eclipsed in 2017 by the NZ Healthy Homes Guarantee Act (56), which established the Healthy Homes Standards (HHS) for rental housing; these came into effect in 2021. With a few exceptions (e.g., injury hazards), the Standards followed the RWoF. An evaluation of the HHS is currently underway.

A national healthy housing standard, written as a model housing code, was released by the American Public Health Association and the National Center for Healthy Housing in 2014 (17) and updated in 2018. The US Centers for Disease Control and Prevention and the US Department of Housing and Urban Development have also released a healthy housing inspection manual. Many housing programs in the United States, including public housing and privately owned housing that benefits from certain subsidies, must comply with Uniform Physical Condition Standards, which are used to identify deficiencies and health hazards in a home's interior, exterior, building system (such as ventilation, electrical, and plumbing), common areas, and the site (the yard) (79).

In the United States, there has also been a proliferation of green healthy housing standards, some of which are required in the context of rebuilding after disasters or with certain subsidies, such as low-income housing tax credits. Numerous studies in low-income housing indicate significant health and indoor air quality improvements, which have been most recently reviewed by the US National Academies of Sciences, Engineering, and Medicine (110) and by the US Department of Energy (171). As in the United Kingdom, these studies have demonstrated significant improvements in self-reported general, physical, and mental health.

Housing and health policies can be centralized or collaborative. In New Zealand, a collaborative partnership among local communities, academics, medical staff, the Ministry of Health, and the private sector has developed a broad-based intervention informed by the WHO healthy housing guidelines (175) called the Healthy Homes Initiative (HHI), which was launched in 2013. The HHI is a secondary prevention program to remediate the rental homes of low-income families whose children have been hospitalized for respiratory or infectious diseases to prevent their readmission into the hospital (129). More than three-quarters of the children are from minority ethnicity homes. An independent, interim outcomes evaluation in 2019 utilizing an integrated (administrative) data infrastructure found that the HHI program had received 15,330 eligible referrals and delivered more than 40,000 interventions to low-income households, resulting in 1,533 fewer hospitalizations, 9,443 fewer general practice visits, and 8,784 fewer filled prescriptions in the first year after the program intervention. The consequent savings to the health care system are estimated to be approximately NZ$10.4 (US$6.7) million annually, with the breakeven investment period expected to be less than 2 years. The results are based on comparing health outcomes for the referred child in the one-year follow-up period to health outcomes in the year prior to the intervention. This finding could be a conservative estimate, as benefits for all household members will be taken into account over a longer time period (130).

INEQUALITIES AND CUMULATIVE DISADVANTAGES

As Shaw (151) highlighted, housing has been not only a core activity area for public health, but also a central component in tackling poverty. Growing international evidence indicates that

disparities in housing are patterned along with other social, demographic, economic, and environmental factors that contribute to the cumulative burden of persistent poor health outcomes in affected groups (3, 4, 57, 76). Children, people with chronic illnesses or disabilities, and older people are more vulnerable to the indoor environment as they spend more time at home (6, 134).

Owning a home is the largest asset for most households, and tenure patterns graphically highlight whether people have an asset base to buffer them in hard times. In the United States, public housing is generally of intermediate quality, compared to unassisted low-income privately owned housing, and government subsides give assisted public housing occupants more discretionary income. A systematic review of holders of US government rental vouchers found that they are less likely to suffer from crowding, malnutrition due to food insecurity, and concentrated neighborhood poverty than are those without vouchers (97). In New Zealand, Indigenous Māori, Pacific, and disabled people and those with low incomes, who have lower rates of homeownership, are more likely to be exposed to poorer rental housing conditions and consequently have higher levels of avoidable housing-related hospitalizations (64). As housing costs are relatively high internationally and consume an increasing proportion of disposable household income, renters have poorer health on most outcome measures of health (128). Even in Germany, where rental rights are protected, renters still have poorer self-rated health due in part to factors such as neighborhood air and noise pollution (131). The quality of the urban neighborhood contributes to this pattern of advantage and disadvantage. More generally, housing affordability is partly determined by the occupants' transport costs, which are in turn affected by the accessibility of public transport (19) and, in some jurisdictions where education is not state funded, by the accessibility and quality of schools.

Stability and Mobility

Insecure housing is historically patterned in many countries by ethnic and income inequality, which adds to cumulative disadvantage. For example, in the United States, when many African Americans moved from the southern to the northern states during the nineteenth century, first the Jim Crow laws and then redlining, gentrification, segregation, and discrimination severely limited the housing that was available to them (43). Similarly, the experience of land loss is an element common to all colonized Indigenous people. Ongoing alienation of Indigenous people's communal land has severely restricted the location, quality, and suitability of housing that is available to them, for example, multigeneration housing. Moreover, land alienation reduces their intergenerational asset base and their cultural connection to their homeland (92, 161).

There has been little research on the health effects of residential mobility and instability (88), particularly for children and adolescents. We know that moving residence is a stressful experience and for tenants is less likely to be voluntary. It reduces the predictability of the environment and disrupts social networks, which can affect well-being. The RCT Moving to Opportunity study voucher scheme involved 4,600 families in five US cities in the 1990s. The experimental group families were able to move from public to private rental housing in different neighborhoods under different conditions. Moving out of high-poverty neighborhoods had a positive effect on mental health, although the effects varied for parents and their children depending on their ages. There were no impacts on the children's education or parents' employment or earnings (96). However, in the long term, results were markedly more positive for children who moved when they were under 13 years old, but children who were adolescents when they moved experienced worse outcomes (136).

A retrospective cohort of children born in 2004, using data from New Zealand's integrated data infrastructure, recorded children's contact with government services to study both the socioemotional behavioral and health effects of moving residence. Of 313,164 children who had completed

a before-school check indicating socioemotional behavioral difficulties at four years of age, more than two-thirds (69%) had moved house since they were born and 12% had moved more than 4 times. There was a linear association between residential mobility and increased socioemotional behavioral difficulties; children exposed to greater residential mobility were 8% more likely to obtain scores of clinical concern than were children exposed to fewer moves (108). Using the same cohort, potentially avoidable hospitalizations were determined from hospital discharge data. Half of the children had moved by age 2, and again the authors found a linear association between higher residential mobility and the increased likelihood of avoidable hospitalization (109).

RENTAL HOUSING, HOUSING PROVIDERS, AND WELL-BEING

There has been comparatively little research into the important ways in which housing services, beyond those directly provided by the dwelling, may underpin generation of positive health and well-being (24). The behavior of both owners and landlords in maintaining their properties in response to incentives, taxation, and regulatory policies is a key factor (23). The Healthy Homes Initiatives have noted that when landlords improve housing quality tenants experience an increased sense of place and greater ontological security (102). Two recent studies, both qualitative and quantitative, focused on tenant well-being while exploring the additional impact of broader organizational processes and factors. In the Housing Through Social Enterprise study, Garnham and colleagues (46) interviewed 75 new social and private tenants in Greater Glasgow, Scotland, using "realistic evaluation" principles (124) to elucidate institutional processes, as well as broader impacts and causal factors. They analyzed data not only on tenants' health and well-being, but also on tenants' perceptions of their housing and the quality of the housing services they had received, as well as on how they had coped financially. As had been previously highlighted in the WHO LARES (Large Analysis and Review of European Housing and Health Status) project (11), Garnham and colleagues concluded that a sense of home was a key to tenants' well-being, as it provided tenants with a space to recuperate from daily pressures and a source of autonomy and social status. This sense of home was underpinned by the services and interventions that the landlords provided. The study raises important questions about the limits to which either social or private housing providers can meet the needs of vulnerable tenants. It suggests that approaches to housing for low-income tenants need to go beyond providing a basic dwelling to successfully intervene in the cycle of poverty, poor housing, and poor health.

Tenant well-being is also the main focus of Public Housing and Urban Regeneration: Maximising Wellbeing, an ongoing, multicenter, multidisciplinary five-year research program in New Zealand that takes a community-based participatory systems approach (74) and focuses on the broader cobenefits of improving public housing in urban areas (22). This program evaluates a major investment in public and affordable housing, as part of urban regeneration, framed by a social, cultural, health, and environmental well-being model aligned to the NZ Government's 2019 well-being framework (137, 141). Working in collaboration with seven public and community housing organizations, the study focuses on the organizations' approaches to how they govern, invest in, and manage their rental properties and the impact of these actions on their tenants' and communities' well-being. The well-being of ~350 tenants is being analyzed and related to the landlords' governance and management arrangements. The study is paying particular attention to the landlords' responsiveness to the constitutionally binding Treaty of Waitangi between the Crown and Indigenous Māori iwi/hapū (tribes/subtribes); the design, quality, and scale of the housing; the quality of the indoor environment and outdoor setting; the formation of the surrounding community and local urban design; and the carbon emissions associated with the operational energy used in the housing and the tenants' transport (20).

TOWARD A MORE INTEGRATED APPROACH

Improving the quality of housing and housing services—so that people can live in affordable, warm, dry, safe houses—is again at the forefront of public health research, policies, and practice, not only to prevent the evident burden of disease (BoD) but to improve the well-being of occupants and the communities in which they live (28, 142, 143), while contributing to environmental sustainability (52).

Following on from earlier work on the environmental BoD associated with inadequate housing in Europe (13), in 2021 researchers estimated from the HHSRS that hazardous housing cost the English health sector £1.4 (US$1.75) billion annually, which together with societal costs (days off school and work and support services) totaled £18.5 (US$23.2) billion annually (38, 47). In New Zealand, a BoD study analyzed the considerable costs of poor-quality housing arising from crowding, cold, damp, or mold and injury hazards linked to falls (138). Hospitalization data, no-fault accident insurance claims, and mortality data were used to estimate the annual BoD from the most severe cases, as well as the resulting costs to the public sector. Using measures of the value of a statistical life, the estimated indirect cost of deaths and direct public-sector costs attributable to these housing conditions were approximately NZ$141 (US$91) million annually, and a total of 229 deaths annually could also be attributable to adverse housing. The costs to society from these deaths were around NZ$1 billion (US$646 million).

The BoD approach is an effort to integrate many aspects of housing in terms of a consistent economic assessment of the health costs of the current housing system, and implicitly the health benefits where better housing is provided, using the dollar value of costs and benefits to compare various policy investments (84). More recently, researchers have considered returns on investments from various interventions (29). Being explicit about the assumptions that drive public health benefits entails considering the effect of assumptions on outcomes (22). To date, this thinking tends to be underpinned by a narrow idea of trade-offs—dollars invested in one area are not available to be invested elsewhere—rather than thinking in terms of complementary positive outcomes in health and well-being. Improving people's living conditions, for example by installing efficient heaters, can reduce hospitalization costs and improve comfort.

Attention is increasingly being given by politicians and policy makers to recognizing the various cobenefits, including health and well-being, from investing in housing and how these might align with outcomes elsewhere in the urban system and beyond. For example, even apart from directly saving health costs from better-quality housing, housing located in activity-friendly neighborhoods may lead to more physical activity and thus generate health benefits, including reductions in the prevalence of obesity (146). Other features of housing can also generate interacting outcomes, such as when more energy-efficient new builds and remediated existing buildings reduce energy use, and at the local and international levels can reduce emissions of pollutants, particularly greenhouse gases.

CONCLUSION

Ways to improve the quality of housing and to consider housing equity are increasingly moving from single-intervention approaches, such as retrofitting insulation, to more comprehensively addressing the overall quality and suitability of housing and neighborhoods. COVID-19 has highlighted that during lockdown periods people have been restricted to dwellings that widely vary in space and amenities, both inside the residence and in the neighborhoods outside. Moreover, the rapid manifestation of climate change is already dramatically highlighting the numbers of people facing extreme temperatures, from both heat waves and cold spells, and in many cases their existing dwellings are inadequate to protect them from extreme weather. Raising the building standards of

new and existing houses is essential for public health and, if done well, can also be an important part of climate mitigation and adaptation.

The enormity of these challenges to the public's health and well-being requires action at many levels but can also provide significant cobenefits. At the global level, the SDGs and the 2019 WHO Housing and health guidelines (175) provide a robust evidence base for coordinated international action, but urgent action is also needed by national and city governments and local communities to enact policies that provide incentives for building better-quality, affordable homes in the right places in a timely way. Of course, generalizing from the research outlined here to other jurisdictions requires caution as conditions vary significantly from country to country. Nevertheless, as the research base is strengthened and advanced from decade to decade, there is considerable potential for policy makers, planners, and communities in different countries to learn from each other and improve both policy and practice.

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AUTHOR CONTRIBUTIONS

P.H.-C. conceptualized the article and was responsible for the overall writing, editing, and finalizing of the manuscript. J.B. contributed to the writing on air quality and ventilation, R.E. contributed to the writing on smoking and indoor air quality, K.N. contributed to editing, D.O. contributed expert knowledge on UK housing and health; and D.J. contributed expert knowledge on US housing and health. All authors contributed to revising and finalizing the article.

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