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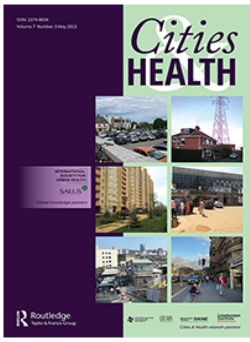

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COMMENTARY AND DEBATE

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Growing evidence that physical activity-supportive neighbourhoods can mitigate infectious and non-communicable diseases

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ABSTRACT

In the early stages of the COVID-19 pandemic, dubious assertions that population density increased spread of the virus led to premature and dangerous recommendations promoting suburban sprawl. In 2020, we published a commentary in *Cities & Health* to refute these recommendations. We hypothesized that features of activity-supportive environments, including high density, would be protective from severe COVID-19 outcomes. The goal of the present commentary is to examine evidence that has emerged during the pandemic to evaluate veracity of the predictions and recommendations we made in 2020. An updated analysis of cities from each continent supports our 2020 analysis that population density is not associated with COVID-19 mortality. Our earlier recommendations to promote activity-supportive environments to benefit both infectious and non-communicable diseases, and to ensure equity of access to such environments, are now supported by empirical studies. Evidence related to public transport shows mitigation of risk could be achieved by limiting riders, travelling during off-peak hours, enforcing physical distancing, requiring face coverings, and implementing strict cleaning protocols. There is substantial evidence that environmental features and interventions that support COVID-19 mitigation strategies also have additional health, environmental sustainability, and economic benefits.

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Population density; COVID-19; public transit; walkability; physical activity

Introduction

In the early stages of the COVID-19 pandemic, unfounded fears fuelled dubious claims that population density increased spread of the virus. These concerns were first expressed through news and social media posts that held residential density and public transit use responsible for COVID-19 infections and deaths (Badger 2020). The logic behind this perception was that population density increased an individual's contact rate, leading to more face-to-face interactions, thereby increasing the basic reproduction number (called 'R' number by epidemiologists) of the virus and leading to hotspots and larger outbreaks (Sy *et al.* 2021). Some government leaders and prominent commentators promoted suburban sprawl to save lives during the pandemic (Kolko *et al.*, 2021, Governor Andrew Cuomo 2020, Peiser and Hugel 2022).

In 2020 (released online July 2020; in print 2021), we published a commentary in *Cities & Health* to refute what we considered to be premature conclusions and dangerous recommendations (Adlakha and Sallis 2021). We argued the benefits of living in walkable or activity-supportive environments for physical activity and non-communicable diseases (NCDs) were well-documented. Because physical activity improves functioning of the immune system in multiple ways (Simpson and Katsanis 2020, Baker and Simpson 2021, Valenzuela *et al.* 2021), and people with NCDs constituted the vast majority of COVID-19 hospitalizations and deaths (Azarpazhooh *et al.* 2020, Hacker *et al.* 2021), we hypothesized that features of activity-supportive environments, including high density, would be protective from severe COVID-19 outcomes, due in large part to physical activity benefits. Because NCDs are responsible for 70% of global deaths worldwide every year (World Health Organization 2019), we argued it would be dangerously misguided to recommend reducing density and increasing sprawl to improve health based on a once-in-a-century pandemic. We pointed out that, instead of density facilitating high transmission of the virus, the actual risk came from crowding in some workplaces, small apartments with multiple families, and public transit without mitigation efforts. We also provided data from 41 international cities showing

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COVID-19 case rates and mortality rates were not correlated. Instead, the trend was for fewer COVID-19 cases and deaths in higher-density cities.

The goal of the present commentary is to examine evidence that has emerged during the pandemic to evaluate the veracity of the predictions and recommendations we made in the 2020 commentary. We summarize new evidence on the impact of pre-diagnosis physical activity on COVID-19 outcomes among adults. We report emerging evidence on the relation of built environment features to COVID-19 death rates. We update our analysis of associations between population density and COVID-19 death rates based on over 2 years of pandemic experience. We examine evidence of COVID-19 transmission on public transit. In light of the new evidence, we reconsider our recommendations.

New evidence

Physical activity, NCDs, & COVID-19 outcomes

Our 2020 commentary was based on extensive evidence that activity-supportive built environments featuring high density, mixed land use, connected streets, and access to recreation facilities, along with other elements, are associated with more physical activity (Ding and Gebel 2012, Smith *et al.* 2017, Elshahat *et al.* 2020), and lower rates of multiple NCDs and their risk factors among residents (Malambo *et al.* 2016, Chandrabose *et al.* 2019). Thus, calls to reduce density and restrict access to outdoor recreation space would be ill-advised, even during the pandemic. That logic still holds, and the significance of the interconnections among built environments, physical activity, and NCDs has become clearer. From the beginning of the pandemic, about 95% of COVID-19 hospitalizations and deaths were among people with NCDs (Azarpazhooh *et al.* 2020, Hacker *et al.* 2021). Thus, several authors have argued the COVID-19 pandemic has been mischaracterized, and that it is, in fact, a 'syndemic' consisting of multiple interacting pandemics. The additional pandemics include NCDs. In some countries, substantial socioeconomic, racial, and ethnic disparities in COVID-19 outcomes have been identified, justifying the inclusion of health and social inequities as a third component of the syndemic (Harris 2020, Gibertoni *et al.* 2021, Kulu and Dorey 2021, Pierce *et al.* 2021, Yang *et al.* 2021). Based on the syndemic conceptualization, it would be important to continue working toward creating more activity-supportive built environments and enhancing equity of access to those environments, as an integral part of syndemic control, alongside now-familiar infectious disease protections such as vaccinations, masking, and physical distancing.

During the pandemic, the direct benefits of physical activity for infectious diseases in general, and COVID-19 in particular, came into sharper focus. It was known prior to COVID-19 that active muscles produced compounds that improved immune system function in multiple ways, reduced inflammation, and enhanced the effectiveness of vaccinations. This literature was not well-known, but a meta-analysis (Chastin *et al.* 2021) and several commentaries summarized the evidence during the pandemic (Simpson and Katsanis 2020, Erhan 2020, Laddu *et al.* 2021). It is notable that the World Health Organization recommended physical activity as a pandemic control measure early in the pandemic (World Health Organization 2018), but it appears few countries made specific recommendations to their populations as part of their pandemic control efforts.

The benefits of physical activity for stress and mental health problems have been known for decades (U.S. Department of Health and Human Services 2008), and this is clearly a relevant benefit during the pandemic, which has been a global stressor and triggered mental health crises (Moreno *et al.* 2020, Pfefferbaum and North 2020). Recommending and promoting physical activity could have prevented some of the mental health effects. Because the stress hormone, cortisol, interferes with the function of immune and inflammation systems, and physical activity is one of the most effective ways of bringing cortisol back into balance (Adam *et al.* 2017), this is another pathway by which physical activity could have reduced detrimental impacts of COVID-19. These documented physical activity benefits suggest widespread closures of places where people are commonly active, especially outdoor locations such as sidewalks, parks, and trails, which could have been counterproductive by diminishing the body's ability to fight infections. Dozens of studies from several countries reported declines in physical activity and increases in sedentary time in youth and adults during the pandemic (Caputo and Reichert 2020).

The prior literature suggested physical activity could help prevent severe COVID-19 outcomes, but it was important to test this hypothesis directly. There have now been almost 30 studies conducted during the pandemic on this topic. Almost all of them were prospective and used pre-pandemic measures of physical activity or fitness to predict COVID-19 outcomes among samples of infected adults. The US Centers for Disease Control and Prevention (CDC) conducted a systematic review of 25 studies and judged that the results provided 'consistent' and 'conclusive' evidence that physical inactivity is a risk factor for COVID-19 outcomes including hospitalization and death (Hill *et al.* 2022). A meta-analysis was conducted of 16 studies that used various measures of physical activity with over 1.8 million adults (Ezzatvar *et al.* 2021). Most studies adjusted for demographics and some NCDs. The overall result was that physically active patients were 34% less likely to be hospitalized and 43% less likely to die from COVID-19. A study of over 48,000 patients found physical inactivity was the strongest modifiable risk factor for severe COVID-19 outcomes (Sallis *et al.* 2021). We were not able to find any studies about the value of physical activity as an adjuvant to COVID-19 vaccinations, so we recommend that such studies be conducted.

Though there is a great deal of evidence supporting (a) physical activity's direct effects on COVID-19 through immunity and inflammation benefits and (b) physical activity's indirect effects on COVID-19 through its benefits for numerous chronic diseases, in our observations, physical activity has not been widely recommended as a means of mitigating the impact of COVID-19.

Built environment and COVID-19 outcomes

Since 2020, a handful of studies have investigated the relation between the built environment and COVID-19. Studies from early in the pandemic focused on population density and produced conflicting results, with findings of no association (Carozzi 2020), negative association (Hamidi et al. 2020a, 2020b), and positive association with COVID-19 mortality (Bray *et al.* 2020, Kodera *et al.* 2020). Associations of density with COVID-19 infections were similarly mixed, but infection data were less reliable.

Using data through January 2021, Frank and Wali measured a broad range of activity-supportive built and natural environment features (e.g. density, design, destination accessibility, and greenness) across US counties and observed favourable and significant associations between built and natural environment features and COVID-19 mortality. The results showed obesity (an NCD) partially explained associations between environmental features and COVID-19 outcomes (Frank and Wali 2021). Wali and Frank conducted a more detailed analysis of neighbourhood-level built environment attributes in King County, WA, along with travel modes. Mixed land use and street connectivity were associated with fewer COVID-19 hospitalizations and deaths. Sedentary (vehicular) travel was associated with higher COVID-19 mortality, and active travel was associated with lower mortality (Wali and Frank 2021). Research during the pandemic shows that, rather than promoting contagion and severe outcomes, there are several pathways by which dense, transit-rich, green, and activity-supportive environments may reduce the risk of COVID-19 as well as NCDs (Hamidi *et al.* 2020a, Adlakha and Sallis 2021).

Public transport use and COVID-19 transmission

Public transport environments (e.g. trains and buses) are characterised by confined, often crowded, environments with surfaces that are frequently touched (buttons, handles) by large numbers of people mixing for extended periods of time. Before mask-wearing was introduced as a preventive measure, COVID-19 transmission was identified on a bus journey in China in the early days of the pandemic (Shen *et al.* 2020). New evidence shows that the risk of COVID-19 transmission in trains significantly varies, with risk from co-travel time and seat location demonstrating the importance of physical distancing (Hu *et al.* 2021). We could not find studies that evaluated the impact of public transport risk-reduction tactics on COVID-19.

In our 2020 commentary, we included a table summarizing the relation of several built environment and transportation variables to NCDs (based on substantial evidence) and infectious diseases (based mainly on indirect evidence). Table 1 updates the prior table with a new column incorporating evidence obtained during the COVID-19 pandemic/syndemic. Only a few relevant studies could be located, so we encourage investigators to conduct more studies on this important topic. The preponderance of evidence is that population density does not increase the risk for COVID-19 mortality. One study shows a favourable relation between mixed land use and COVID-19 outcomes, and several studies show that the use of public transport (without mitigation measures) has an unfavourable relation to COVID-19 outcomes. Overall, the new evidence supports the predictions we made about relations to infectious diseases we made in our 2020 commentary (Adlakha and Sallis 2021).

New analyses of population density and COVID-19 mortality

To update our 2020 analysis of the association between population density and COVID-19 mortality, we employed a multi-stage sampling process to identify a broadly representative set of cities for which up-to-date and comparable data were available. From a manual audit of available COVID-19 mortality data for a shortlist of 54 low-, medium- and high-density cities across Africa, Asia, Europe, Latin America and the Caribbean, Northern America, and Oceania, we were able to align 37 of these with geographically matched records for deaths per 100,000 population that were approximately up to date (ranging from 24 April to 17 August 2022) (Nigeria Centre for Disease Control 2022, South African Medical Research Council, Johns Hopkins University Center for Systems Science and Engineering, Fast-Track Cities 2014, 2014, Sortir Paris, Regione Lombardia, Government of the Netherlands, LG Inform 2022a, 2022b, Greater London Authority, SALURBAL 2022, Drexel Urban Health Collaborative and Big Cities Health Coalition, Arizona Department of Health

Table 1. Summary of expected net effects of built environment attributes on non-communicable diseases and infectious diseases.

Environmental attribute	Expected net effect on non-communicable diseases	Expected net effect on infectious diseases	New evidence of relation to COVID-19 mortality
Residential density	+	0	+ (Hamidi et al. 2020a, 2020b, Frank and Wali 2021)(Figure 1) 0 (Carozzi 2020, Adlakha and Sallis 2021) - (Bray *et al.* 2020, Kodera *et al.* 2020)
Mixed land use	+	+	+(Wali and Frank 2021)
Automobile-optimized transportation system	-	+	
Public transportation	+	-	- (Shen *et al.* 2020, Hu *et al.* 2021, Qian *et al.* 2021)
Pedestrian & bicycling facilities	+	+	n/a
Parks, trails, open space	+	+	n/a
Open streets initiatives (e.g. creating pedestrian and cycling streets closed to motor vehicles)^	+	+	n/a

+ = favourable effect; 0 = no effect; - = unfavourable effect; n/a = not applicable (no relevant studies found).
This table represents a simplification because possible unfavourable effects of density and public transport use on infectious diseases can be mitigated by public health interventions.
^ Open Streets initiatives, also called Ciclovía programs, allow community members to gather, socialize, walk, run, bike, skate, dance, or participate in other activities on streets temporarily closed to motorized traffic.

Services 2022, Queensland Government, Ministry of Health NZ). Population density statistics corresponding to the varying geographic scales of each city's COVID-19 mortality reporting catchment were sourced (for example, city, county, metropolitan and urban area estimates). Due to the diversity of included cities, Wikipedia was drawn upon as a consistent source of contemporary population density estimates for the relevant city catchments. Detailed notes and code on this process, including urban centres for which data were not able to be located, are provided as supplementary material. Our code and data can be accessed at https://github.com/carlhiggs/urban_density_covid_linkage.

The final set of matched population density and COVID-19 mortality estimates for 37 cities through mid-2022 are presented in Table 2. A scatterplot of cumulative deaths reported due to COVID-19 per 100,000 population by population density per square kilometre is presented in Figure 1.

Despite considerable heterogeneity both within and between the regions of the sampled cities, overall urban population density appears to have a weak, negative association with COVID-19 mortality rates (Pearson correlation coefficient, $r = -0.139$). We conducted sensitivity analyses by excluding the high-density city outliers. Excluding Delhi and Lagos (Supplementary Figure S1) did not change the inference that there is no evidence for a positive association between population density and COVID-19 mortality using the statistics included in our study (Pearson correlation coefficient, $r = -0.035$). The observed weak negative trend was slightly amplified by excluding the outlier city of New York along with Delhi and Lagos (Supplementary Figure S2; Pearson correlation coefficient, $r = -0.142$).

There are several limitations to this analysis. Approaches to, and accuracy of, the classification of COVID-19 mortality may vary across the included cities, and this would impact the reporting and interpretation of statistics across the included cities. Most likely, the result would be an underestimation of the true rates (Oliver 2021). However, to mitigate against this risk and maximise comparability, we restricted the analysis to cities for which we were able to identify appropriate urban statistics and corresponding catchment areas. Reporting catchments did vary between cities; however, these broadly did represent greater metropolitan regions. Finally, due to the need for manual data sourcing and linkage, our included sample of 37 cities was not comprehensively representative of the diversity of the six broad geographical regions where they are located. Restricting our analysis to the top three cities of density tertiles for each region captured some diversity in the type of cities while limiting the scope of our investigation to a manageable level. However, in Oceania in particular, it meant that cities and towns of smaller Pacific islands were not included. We were able to locate comprehensive COVID-19 data for Latin American cities (through the SALURBAL project) (Collaborative DUH 2017). However, this was not the case for most cities where country wealth was not a reliable predictor of granular reporting on COVID-19 mortality. For example, mortality statistics in Australia were only released at the state or territory level for most jurisdictions, which meant these could not be sourced specifically for Adelaide, Melbourne, Newcastle, Perth, or Sydney.

Recommendations

After almost 3 years of the COVID-19 pandemic (or more accurately, syndemic), we revisit the recommendations we made during the first year. Our 2020 commentary in *Cities & Health* (Adlakha and Sallis 2021)

Table 2. Population, area, density, and COVID-19 mortality estimates for 37 cities across six geographical regions. See supplementary material for sources and retrieval notes.

Country	City	Population	Area (km^2)	Population density	Cumulative deaths reported due to COVID-19 (mid-2022)	Deaths per 100,000 population
Africa						
Nigeria	Lagos	21,320,000	2,707	7,876.8	771	3.62
South Africa	Johannesburg	8,000,000	3,357	2,383.1	22,143	276.79
Asia						
China	Guangzhou	65,594,622	19,870	3,301.1	8	0.01
	Shanghai	41,354,149	14,923	2,771.2	595	1.44
India	Delhi	16,787,941	1,484	11,312.6	26,376	157.11
Indonesia	Jakarta	33,430,285	7,063	4,733.5	15,304	45.78
Japan	Osaka	8,823,358	1,905	4,631.3	5,313	60.22
	Tokyo	40,700,000	13,452	3,025.6	8,700	21.38
Thailand	Bangkok	14,626,225	7,762	1,884.4	7,974	54.52
Europe						
France	Paris	13,024,518	18,941	687.6	6,119	46.98
Germany	Berlin	6,144,600	30,546	201.2	4,739	77.12
Italy	Milan	3,236,472	1,575	2,054.9	12,399	383.10
Netherlands	Rotterdam	651,157	324	2,008.9	1,170	179.68
Russia	Moscow	13,010,112	2,562	5,079.1	44,677	343.40
United Kingdom	Birmingham	2,919,600	599	4,874.9	3,718	127.35
	London	9,002,488	1,572	5,726.8	19,102	212.19
	Manchester	2,812,569	1,276	2,204.2	1,392	49.49
Latin America and the Caribbean						
Argentina	Buenos Aires	15,624,000	4,758	3,283.7	56,553	361.96
Brazil	Curitiba	3,400,100	15,417	220.5	13,129	386.14
	Goiânia	2,654,860	739	3,592.5	10,783	406.16
	Rio de Janeiro	12,280,702	4,540	2,705.1	54,705	445.45
	São Paulo	22,001,281	7,947	2,768.5	76,368	347.11
Mexico	Ciudad Juárez	1,501,551	321	4,675.0	3,223	214.64
	Mexico City	21,804,515	7,866	2,772.0	53,718	246.36
	Monterrey	4,689,601	7,658	612.4	12,310	262.50
Peru	Lima	10,882,757	2,819	3,860.1	9,734	89.44
Northern America						
United States	Chicago	2,746,388	607	4,521.25	7,738	281.75
	Dallas	2,613,539	2,353	1,110.68	6,820	260.95
	Detroit	1,793,561	1,740	1,030.78	8,122	452.84
	Houston	2,304,580	1,740	1,324.76	11,176	484.95
	Indianapolis	977,203	1,044	936.20	2,910	297.79
	Los Angeles	9,861,224	12,310	801.07	32,324	327.79
	New York	8,804,190	1,224	7,195.38	35,185	399.64
	Phoenix	4,420,568	23,890	185.04	17,692	400.22
Oceania						
Australia	Brisbane	2,560,700	15,842	161.64	804	31.40
	Gold Coast	640,778	414.3	1,546.65	261	40.73
New Zealand	Auckland	1,463,000	607.1	2,409.82	118	8.07

was stimulated by misguided calls to reduce population density in order to limit opportunities for viral transmission. Though a couple of studies have reported positive associations between density and COVID-19 mortality (indicating higher risk) (Bray *et al.* 2020, Kodera *et al.* 2020), three published studies reported either zero or negative correlations (indicating lower risk) (Carozzi 2020, Hamidi et al. 2020, 2020, Frank and Wali 2021), as did our 2020 analysis and updated analysis in the current paper with samples of international cities. Early reports of population density and COVID-19 cases were mixed, but with more studies reporting no or negative associations (Carozzi 2020, Hamidi et al. 2020a, 2020b) than reporting positive associations (Kulu and Dorey 2021, Jamal *et al.* 2022). However, we consider the data on cases too unreliable to justify comparisons across cities. It is notable that some of the world's most densely populated cities – for example, Hong Kong, Singapore, Taipei, and Seoul – managed to successfully control the outbreak of coronavirus using common mitigation tactics (Density is Not the Problem 2020). Because there is no convincing evidence that population density increases risk of COVID-19 outcomes, and there is substantial evidence of favourable associations with physical activity and NCDs (Ding and Gebel 2012, Malambo *et al.* 2016, Smith *et al.* 2017, Chandrabose *et al.* 2019), we can more confidently support existing recommendations to increase population density as part of efforts to make cities healthier and more sustainable (Community Preventive Services Task Force, (CPSTF) 2017, World Health Organization 2018). We continue to assert that it is crowding in specific environments, including workplaces, housing, entertainment venues, and public transit (without mitigation), that creates higher risks of viral transmission. Preferred solutions are to use commonly advised mitigation measures, such as improving ventilation, enforcing physical distancing, wearing face coverings,

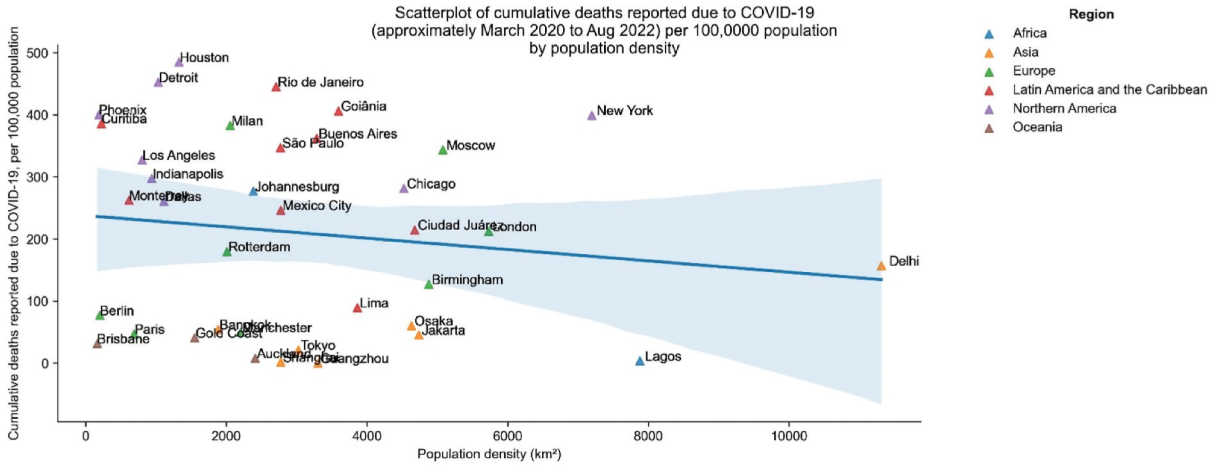

Figure 1. Scatterplot of cumulative deaths reported due to COVID-19 per 100,000 population by population density per square kilometre, for 37 cities across six regions in mid-2022.

implementing strict cleaning protocols, installing physical barriers (e.g. sneeze guards and partitions), reducing maximum occupancy, and increasing transit service on overcrowded routes.

We are also more confident in reaffirming our recommendation that increasing access to activity-supportive environments is likely to be an effective approach to reducing risk of severe COVID-19 outcomes (Adlakha and Sallis 2021). Although only a couple of studies could be located that examined associations of multiple activity-supportive built and natural environment features with COVID-19 mortality, their results generally supported our 2020 hypothesis (Frank and Wali 2021, Wali and Frank 2021). Activity-supportive environments are already recommended for promoting physical activity (Community Preventive Services Task Force CPSTF 2017, World Health Organization 2018), which was shown to be protective from severe COVID-19 outcomes during the pandemic (Ezzatvar *et al.* 2021, Hill *et al.* 2022) through well-documented biological mechanisms (Simpson and Katsanis 2020, Chastin *et al.* 2021). There is substantial evidence that environmental features and interventions that support COVID-19 mitigation strategies also have additional health, environmental sustainability, and economic benefits (Sallis *et al.* 2015, Rojas-Rueda and Morales-Zamora 2021, Giles-Corti *et al.* 2022).

We are concerned that the benefits of activity-supportive environments, and physical activity itself, have not been widely recognized during the pandemic. Though the WHO recognized physical inactivity as a risk factor for COVID-19 and recommended physical activity (World Health Organization), very few countries specifically promoted physical activity as a pandemic control tool. Instead, early in the pandemic some of the most common places for physical activity such as schools, health clubs, parks, and trails were closed. These closures and other restrictions likely explain the declines in physical activity and increase in sedentary time that have been reported worldwide (Caputo and Reichert 2020). On the positive side, there are reports that many cities around the world closed streets to automobiles so people would have more space where they could be active while allowing safe physical distancing (Combs). Though we could not find evaluations of such 'open street' interventions regarding COVID-19 outcomes, we continue to recommend open streets as a promising built environment intervention to enhance health.

There is overwhelming evidence COVID-19 had inequitable effects on people with lower incomes and racial, ethnic, and religious minorities (Harris 2020, Gibertoni *et al.* 2021, Kulu and Dorey 2021, Yang *et al.* 2021). The inequities were very likely due in large part to crowded housing conditions, 'essential' jobs in crowded settings or those requiring exposure to many people, along with generally higher levels of multiple NCDs (Pierce *et al.* 2021). However, it is clear that cities provide inequitable access to healthy activity-supportive environments, as was recently illustrated among 25 international cities (Boeing *et al.* 2022). Thus, creating more equitable access to activity-supportive built environments should be part of efforts to prepare for future infectious disease pandemics, while continuing to promote activity-supportive environments for their NCD benefits.

A few authors have expressed concerns that some of the key lessons from the pandemic have not been learned by infectious disease and government leaders (Rutter *et al.* 2020, Ma and Sallis 2022). Even when discussing 'new' strategies for pandemic control, advisors to several governments proposed variations on the main infectious disease strategies related to medical system preparedness, infection mitigation measures, vaccines, and medications (Abbasi 2022). We assert that NCDs and health inequities qualify as major global problems, and that their strong interconnections with COVID-19 have been well-documented (Nikoloski *et al*. 2021). Thus, we recommend the COVID-19 pandemic be recognized as a syndemic, and new syndemic control strategies be systematically developed by interdisciplinary teams that include experts in chronic diseases, health equity, health behaviours, built environments, and communication, in addition to infectious disease experts.

Conclusion

Evidence about the potential for built environment interventions to be part of pandemic/syndemic control efforts is still emerging, and we urge continued study of the topics covered in this paper. However, there is sufficient evidence to justify including built environment, physical activity, and NCD data in infectious disease prediction models that are used to inform public health strategies. Omission of such evidence in current COVID-19 models prevented consideration of potential negative side effects of closing common places for physical activity. Improved models would account for the potential benefits of making temporary or permanent built environment changes facilitate physical activity and provide equitable opportunities for communities at high risk to be physically active.

Disclosure statement

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Data availability statement

The data supporting this study's findings are available from https://github.com/carlhiggs/urban_density_covid_linkage

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