Article

Cities need an integrated and holistic approach to health adaptation in climate planning

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Despite critical intersections between exposure to the impacts of climate change and public health, barriers to implementing health adaptation remain. A strong commitment from city governments could be a solution. We reviewed 55 city climate adaptation plans from 2016 to 2024 for health comprehensiveness, dimensions of health (physical, mental and social), equity and vulnerability, and implementation readiness. Here we found that 20% of cities did not meaningfully include health, 29% acknowledged the health impacts of climate change but did not have health-related adaptation strategies, 40% considered some level of health-related adaptation strategy and 11% had health-specific adaptation strategies, but no plans matched our definition for having a prioritized and holistic integration of health. Only six cities—Chennai, Dar es Salaam, Delhi, Salvador, Singapore and Tshwane—had comprehensive health interventions outside of heat and air pollution. Plans most commonly do not focus on mental health or social capital, and plans also tend to neglect compelling areas of equity, justice and implementation. As such, our analysis shows that the awareness of health impacts is prevalent at the city level, but the integration of holistic health strategies in adaptation plans still lags.

Climate change has become a substantial and systemic threat to human health[1–4]. The World Health Organization (WHO) estimates that climate change will cause 250,000 additional deaths per year—or 5 million deaths every 20 years—through factors such as increased heat stress, exacerbated malnutrition or changes in the spread of malaria—and at least US$2 to US$4 billion a year in additional direct healthcare burdens[5]. WHO also reports that 3.6 billion people live in areas extremely vulnerable to climate change impacts and that the death rate from extreme weather events in vulnerable regions such as low-income countries or small island developing states is 15 times higher than less vulnerable ones over the past decade[5]. Heat extremes in cities have equity implications, too, as they are the most dangerous for female and older urban residents[6], or for people that are unhoused or living in precarious housing[7]. Mental health conditions present both a vulnerability to and outcome of climate hazards[8,9].

The urgency and severity of these estimations make climate change one of the most pressing health concerns of the modern era, rivaling and compounding that of global pandemics such as COVID-19, which now has an estimated excess mortality of over 14 million deaths[10]. Moreover, one review of global funding patterns concluded that between 1985 and 2022, only 0.26% of research funding awarded by the National Institute of Health related to climate change, and only 0.70% of funded projects globally in the Dimensions database related to climate change and human health[11]. Similarly low levels of funding are distributed to health adaptation projects through bilateral and multilateral funding sources[12].

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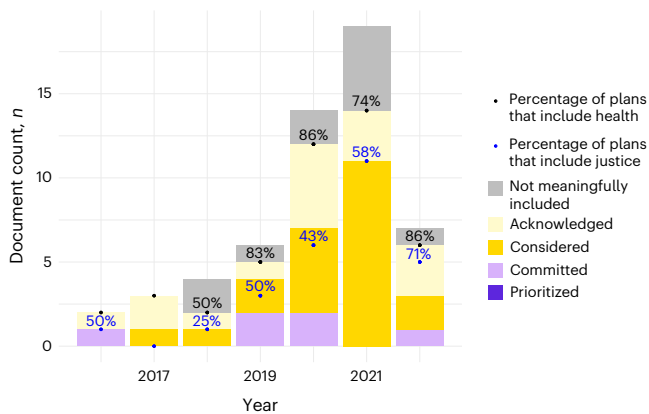
Fig. 1 | An overview of the health prioritization level of climate change adaptation plans in a sample of C40 cities. Each year is divided by the health prioritization level. The total percentage of plans that included health and equity per year is also included.

Recent years have seen an increase in health presence in global climate policy[13]. Notable milestones include the COP26 Health Commitments[14], the COP28 Declaration on Climate and Health[15] and the 77th World Health Assembly Resolution on Climate Change and Health[16]. WHO works with the Ministries of Health to develop Health in National Adaptation Plans (HNAPs), which supplement other national planning tools such as national adaptation plans (NAPs) and Nationally Determined Contributions[17,18]. However, tracking from WHO shows low levels of plan execution and implementation[19,20]. Further, national planning requires local implementation.

One might, therefore, expect a concomitant commitment from local public health agencies and city administrations. A few studies have analyzed health content in city climate adaptation planning, but are already out of date or narrow in their focus[21,22]. For example, a global baseline assessment of 401 cities found that only 10% of cities included public health adaptation in their planning and that it was more common in cities in high-income countries[21]. Sheehan et al.[23] built on this review by looking at specific health adaptation actions in 22 large cities.

Although there has been a start in the literature to understand what cities are doing on climate and health, there remain many gaps. Mental health has not been included in health metrics and majority of climate–health action has focused on heat action planning[21,22] Here we ask: what are the health and equity patterns for climate change adaptation within a sample of global cities? To answer this question, we explore data from 55 city plans for climate adaptation from 2016 to 2024.

In doing so, our aim is to make empirical, methodological and conceptual contributions. Empirically, we take a novel approach to this research by expanding on the work in ref. 22. Their work took a governance approach, focusing on the role of city health actors across the presence of five physical health indicators, with a sample of only 22 cities. Here we take an expanded approach, with a more recent and larger sample of 55 cities, to assess the level of health integration of city plans across 13 different indicators spanning health, equity and implementation readiness. Methodologically, ref. 22 used the CDP 2018 City Adaptation Action Database and, therefore, was unable to represent notable recent events that could influence health integration including the COVID-19 pandemic, the COP26 Health Commitments and the COP28 Declaration on Climate and Health. Conceptually, we expand the traditional focus of health adaptation by classing health adaptation across physical, mental and social health indicators, and we also analyze how health and equity co-occur in city adaptation planning. So far, studies have analyzed city climate policy either on health or justice. However, there are notable overlaps between the two with the health status heavily influenced by

unjust policy. Further, a holistic approach to health is missing from climate policy, with physical health is the primary focus of health adaptation[24]. We aim to present a more holistic interpretation of health by integrating equity, social, mental and physical health in one synthetic analysis.

Results: health prioritization and integration across 55 cities

Our final group of 55 cities represented all world regions. East Asia and Pacific was the most represented region (24%) followed by Europe and Central Asia (20%), Sub-Saharan Africa (16%), Latin America and Caribbean (16%), North America (15%), South Asia (5%) and Middle East and North Africa (4%). Almost half of the plans were from high-income countries (47%), with the other 53% representing low- and middle-income countries (upper middle, 33%; lower middle, 18%; low, 2%). Most of the plans were approved since 2020, with 73% of plans being approved between 2020 and 2022. The plan type varied with a majority of plans (78%) integrated climate plan (mitigation and adaptation), 15% were standalone adaptation plans and 7% were other plans—all-hazard mitigation plans, resilience plans or wider development plans—that included a section on climate action.

When analyzed by health prioritization level, 20% of cities did not meaningfully include health in their plans (not meaningfully included), 29% acknowledged the health impacts of climate change but did not have health-related adaptation strategies (acknowledged), 40% considered some level of health-related adaptation strategy (considered), 11% had health-specific adaptation strategies (committed), and no plans matched our definition for having a prioritized and holistic integration of health (prioritized; Fig. 1)

On average, 80% of plans included health in some capacity (acknowledged and above), whereas only 50% included health-relevant adaptation strategies (considered and above) and just 11% had health-specific adaptation strategies (committed and above). Similarly, only 49% of plans included justice or equity. Year of publication had little effect on the health prioritization categorization (Fig. 1). For example, 2021 had the most plans (n = 19) but the second lowest consideration of health (74%), second only to 2018.

When viewed by income class, cities in high-income countries had lower levels of health prioritization than those in low- and middle-income countries (Fig. 2). As shown in Fig. 2, no cities strongly prioritized an integrated notion of climate change and health, and only six cities had dedicated sections on health interventions, including on health systems strengthening: Chennai, Dar es Salaam, Delhi, Salvador, Singapore and Tshwane. Only 30% of the cities in high-income countries included health adaptation strategies (considered and above), whereas 69% of the cities in low- and middle-income countries did. When broken down by geography, Sub-Saharan Africa and Latin America had the strongest integration of health (88% considered and above) followed by South Asia (67%). East Asia and Pacific (38%), Europe (36%), North America (12%) and the Middle East (0%) were largely behind the three leading regions on their health integration.

Our findings were geographically similar to the UNEP Adaptation Gap Report with Latin America, Africa and Asia-Pacific having a higher presence of health actions than European and other states[25]. However, our analysis contradicts the findings of other studies, which found more health adaptation in high-income countries[21]. In these studies, health still made up a larger percentage of adaptation strategies in cities of lower-income countries[22,23].

Low levels of health integration in plans are similar to other studies, 11% in our study compared with 10% in ref. 21. Highly health adaptative cities were also studied and health department involvement was found only in heat planning and that stronger health engagement is needed[22]. Further, the distinction between health
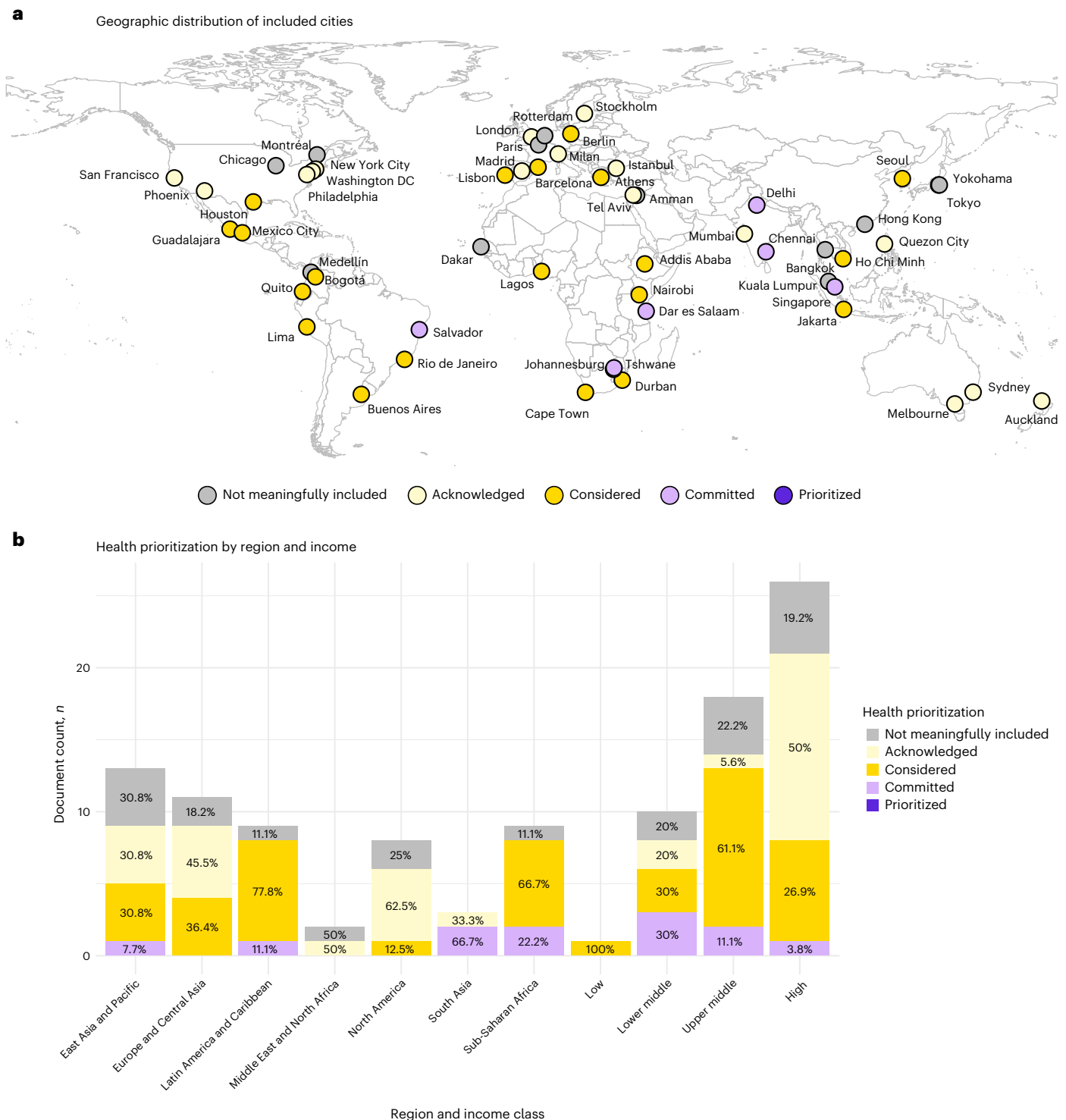
Fig. 2 | Geographic and income distribution of included cities stratified by health prioritization level. a, Names of all the cities included. Purple cities had higher health prioritization levels. **b**, Health prioritization level varied across geographic region and income class. World Bank 2025 classifications of country regions and income classes were used for each city. Base map from Natural Earth (https://www.naturalearthdata.com).

awareness and health action is becoming more pronounced. Our findings reflect this with many plans acknowledging health impacts (80%), but only 11% having strong health adaptation strategies (committed and above). This is on par with the global national landscape. The most recent UNEP Adaptation Gap Report found 74% of NAPs had health adaptation priorities; however, when looking at completed and evaluated adaptation projects, only 1% covered the health sector[25]. UNEP reported that of the cities self-reporting to the CDP, only 3% of hazard-specific adaptation planning focused on health and vector-borne diseases[25]. This is compared with health co-benefits, which accounted for a much higher percentage (22%) of co-benefit coverage in the plans[25]. WHO has recently released a summary of health content in national climate planning and found all NAPs and HNAPs reviewed considered some health risks; however, there was a large discrepancy between the health risk and identified adaptation strategies[26].

Discussion: dimensions of health, equity and implementation readiness in C40 plans

City plans not only involve specific regions and income classes but also substantive themes. Thus, each city plan was analyzed based on (1) dimensions of health, (2) equity and (3) implementation readiness.

Dimensions of health

Health was divided into six themes across physical, mental and social health. Figure 3 shows the document themes by year of plan approval, with the subsequent subsections providing more detailed findings per theme. The larger circles over time are representative of more overall documents and not increased proportion of theme prevalence.

Physical health. Here we define physical health indicators as health adaptation that addresses physical health concerns at a systems level—commonly referred to as direct health impacts from climate change. This includes disease burden and risk of injury or death from climate hazards. We coded physical health based on the indicators used in ref. 22. Their health indicators were chosen from commonly referenced climate–health actions in the literature, covering topics of emergency response, mapping, preparedness and heat action[22]. We were specifically interested in adaptation strategies that were human-focused. Adaptation strategies that were focused on built infrastructure without connection to human health were not considered.

Overall, physical health is the most common form of health integration. Out of the plans that included health adaptation strategies (Extended Data Table 1), all but one included at least one physical health component. Hazard and vulnerability mapping was the most integrated, with 56% of plans integrating a hazard and vulnerability assessment into their plan or stating an intention to do so. Also, 51% of plans included early warning systems, out of which 22 were for hazards (floods, droughts and stormwater), 10 were for extreme heat and 2 were focused on disease. Furthermore, 40% of plans included heat actions. This included blue and green infrastructure, operating cooling shelters, awareness and education activities, heat vulnerability mapping, alert and early warning systems, capacity and training at healthcare facilities, altering occupational health standards to reduce exposure, and developing or updating heat action plans. Fourteen plans (25%) included disease surveillance measures.

Some plans included additional adaptation strategies outside of the four categories above. Strategies on climate-resilient health systems included capacity building, training for health staff and first responders, improving access to care and increasing public awareness, climate and health research and plan development, vector control and strengthening of health systems. Two plans included strategies to reduce illness from contaminated food and food procurement, whereas nutrition and food systems were more common. One plan mentioned sustainability of health systems and reducing waste and emissions of health facilities and one plan mentioned implementing a one-health approach. Although strengthening health systems can lead to mental and social co-benefits, this was only coded as a physical health strategy unless mental health was directly mentioned. The core focus of health system strategies was on healthcare delivery and disease.

There were several health-adjacent topics that were commonly covered in plans from an infrastructure or mitigation perspective. These included air pollution, water and sanitation, urban heat islands, and nutrition and food systems. Health was secondary or not included in the content of these sections, and therefore, they were not included in our code strategy as a health adaptation measure. For example, water and waste was discussed as an infrastructure issue in mitigation sections in which health was a co-benefit. It is still important to acknowledge that strategies in these sectors exist, and there is an opportunity to optimize the health benefits and components of these strategies.
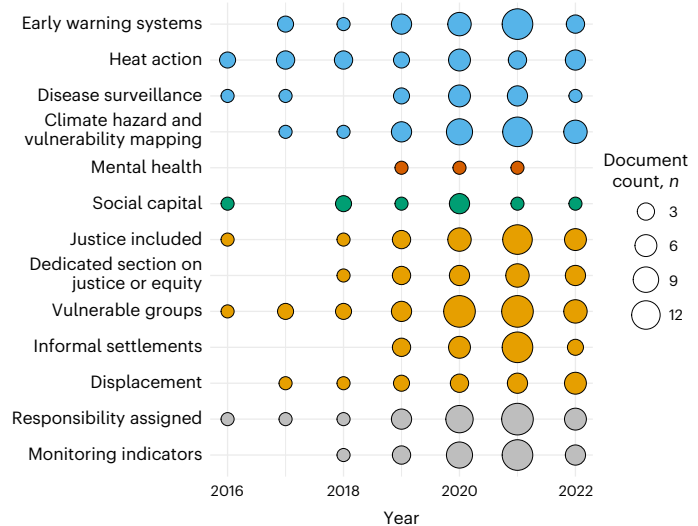

Fig. 3 | Prevalence of health prioritization levels across core climate adaptation themes. Each color represents a thematic group. The blue dots show the physical health themes; dark orange, mental health; green, social capital; orange, justice and equity themes and gray, implementation readiness themes.

Other studies have also found a dominance of physical health in health adaptation literature[27]. So far, physical health is the common understanding of health impacts and health adaptation, and therefore, it is expected that most—if not all—of health integration would focus on physical health components. The emphasis on flooding and heat is similar to other studies[13,21,23].

It is important to note that not all of the strategies included here are a direct health adaptation strategy. For example, hazard early warning systems can be designed and implemented with little regard for health even if they have a health benefit when enacted. Similarly, not all heat action is done through a health framing. As such, it is important to consider the vast array of health topics that are still missing from adaptation discussions at a city level. Future studies can consider a more stringent coding system for climate-resilient and sustainable health systems[18], as well as other adaptation strategies that directly address disease, injury and mortality[23].

Mental health. Previous analyses of city climate plans have had limited inclusion of mental health. We only located one study that reviewed global city adaptation plans and included mental health[23]. As such, we wanted to determine if mental health is included in city adaptation planning, and if so, how it is integrated (Extended Data Table 2). We found that mental health was rarely considered. Houston was the only city to have a dedicated section on mental health, with one of their three mental health strategies specific to climate adaptation. Houston acknowledged the mental toll that previous disasters have had on residents even years later: "Hurricane Harvey Registry found that two-thirds of the respondents reported intrusive or unintended thoughts about Harvey and associated flooding. This trauma is not only from one hurricane, but from repetitive flooding in some neighborhoods as well as daily fears of violence, poverty, isolation and loneliness that many Houstonians experience on a regular basis."

The city's mental health strategy aims to train first responders in psychological first aid to increase the support provided in the aftermath of a disaster. The city included two other mental health interventions not specific to climate change to provide peer-to-peer and professional mental health support to youth. Houston's plan may have been more likely to include mental health as their plan was a city resilience plan, which was not exclusive to climate change. In general, we found resilience plans or climate action plans with a non-traditional format were more likely to include mental health, social health or

equity. Further, the city of Houston has had numerous large-scale disasters (Hurricane Harvey, Tropical Storm Imelda) in recent years, which could have influenced inclusion.

Cape Town included an adaptation strategy on mental health with the broad intention to include mental health in their climate response and to integrate intersections between mental health strategies in the city's resilience plan with their climate actions. Chicago's plan, like Houston's, was a city resilience plan, included mental health strategies outside of climate adaptation. These included training for emergency personal to improve crisis response for individuals with mental illness.

A handful of plans included the words "mental health" either acknowledging there can be mental health impacts to climate change or that there are mental health and well-being co-benefits to some adaptation strategies—blue and green infrastructure, for instance. These occurrences show that there is some awareness of mental health outcomes to climate mitigation and adaptation strategies (both beneficial and maladaptive) at the city level, although significantly less than physical health awareness. There is more ground to gain to achieve comprehensive and direct adaptation strategies targeting mental health.

Very little mental health presence aligns with similar studies. In the typology of urban health adaptation in ref. 23, the authors reviewed 369 actions across 98 cities and found no mental health adaptation strategies. Most research on climate and mental health at the city level focuses on heat as the main exposure[28,29], with most research on climate and mental health, irrespective of geography, centering on quantifying impacts or co-benefits[28,30]. Previous studies have called for increased focus on mental health in climate health and vulnerability and adaptation assessments[27]. Although these assessments can be completed at any level of jurisdiction (municipal, regional and national), majority are completed at a country level[31]. Further, research shows that mental health integration is doing little better at a national level with only 8 out of 38 Nationally Determined Contributions referencing mental health[19,32,33]. WHO recently found similar mental health inclusion in NAPs, with 5% including mental health adaptation strategies[26]. HNAPs performed better still, with 22% including adaptation strategies for mental health[26]. Our findings further confirm gaps on mental health that are prevalent throughout the climate policy landscape and highlights the opportunity for subnational leadership in this area.

Social capital. Social health refers to interpersonal relationships such as the quality of social interactions and community integration, which are considered an essential element of good health and well-being[34]. Here we focus on social capital as the social health proxy for adaptation strategies that enhance community resilience and build social support. Ten plans included elements of social capital. These include social support mechanisms like building resilience hubs and integrating social support into emergency response including elderly support networks and establishing neighborhood emergency plans (Extended Data Table 3). Other strategies focused on overall community cohesion and varied from better understanding social capital to investing in sports, culture, art and education. We did not code specifically by subpopulation (women, children, elderly). However, when subgroups were mentioned, the elderly were most commonly targeted by social cohesion measures. One plan, Rio, specified actions for children including access to education, sports and culture.

Terms related to social capital (community, social cohesion and inclusivity) were most used to refer to public participation and curating both community and community organization involvement in the climate planning progress or for transferring responsibility for adaptation strategies onto community and individual behavior. Although it is important to have public participation in planning processes and having strong public involvement can lead to a stronger focus on equity[35,36], it is not directly relevant to social cohesion as defined here. As such, when these terms were used in this way, it was not coded as being relevant to social health.

Some plans integrated elements of social determinants of health outside of social cohesion. In particular, plans that had a strong equity focus or followed a non-traditional structure (such as Rio or Barcelona) had more strategies addressing social issues. The most common involved providing access to safe, affordable and climate-resilient housing and providing increased access to economic opportunity. There are strong overlaps between social health, equity and vulnerability, particularly with regard to climate resilience. Both housing and income are essential for good health and well-being[37,38] and for resilience to climate impacts[2,39], yet these are not considered standard in climate action planning. Further, community cohesion has been found to improve outcomes after disasters[40] and on the opposite end, social isolation is tied to worse health outcomes[41].

Some studies have looked at the role of social capital in urban case studies. Guardaro et al.[42] explored social capital and urban heat risk. Opoku-Boateng et al.[43] and Shahid et al.[44] examined the role of social capital in informal settlements in Ghana and Pakistan, respectively. All three noted that social capital is an underutilized resource in climate resilience, although there was notable variation in how social capital was defined[42–44]. Examining the social determinants of health in urban centers is not new[45]; however, there has been less integration on their relevance in climate policy. Friel et al.[45] argued for joint action on climate mitigation and adaptation and addressing social determinants of health, whereas others have called the climate crises a determinant of health in its own right[46]. More studies can look at the inclusion of social capital, social cohesion and social resilience as a consideration of social health in climate adaptation. To the best of our knowledge, this has not yet been explored in the literature.

Equity and vulnerability
Unlike health, justice, equity and vulnerability content was coded outside of adaptation strategies. We determined if there was a justice or equity focus across two areas: presence of justice or equity and vulnerable groups (Extended Data Table 4). Presence of justice and equity was determined if the words justice and equity were used and if there was a dedicated section on justice, equity or vulnerability. We did not further code by type of justice as this has been looked at by other studies[35]. Plans were considered to have discussed vulnerable groups if there was dedicated text on population groups that were at a differentiated risk than the general population. We further looked at two specific elements that enhance vulnerability, namely, displacement and informal settlements.

We found that almost half (49%) of the plans sufficiently included justice, with 33% having a dedicated section and 65% using the words justice or equity. Plans that only vaguely mentioned that climate change has inequitable impacts but did not integrate justice into their approach were not classed as having sufficiently included justice but were coded as having used the words justice or equity when applicable. Also, 75% of plans mentioned vulnerable populations, with varying levels of inclusion. This could be one or two sentences up to a dedicated section on vulnerability and specific adaptation strategies. Furthermore, 40% of plans mentioned informal settlements and 29% mentioned climate displacement.

Overall, justice and equity content were most discussed in the background sections. Some plans grounded their whole approach from a justice framework by incorporating it in the plan's goal. However, similar to health, there was often limited follow-through on integrating justice into the adaptation strategies. Three plans also used a strong gender lens in addition to an equity lens. The word "inclusion" was commonly used to denote themes of justice or equity, with some plans even using inclusion as a third pillar of the plan after mitigation and adaptation.

When looking at content related to displacement, climate displacement was most commonly mentioned in relation to climate hazards or sea-level rise that could lead to displacement of populations within the
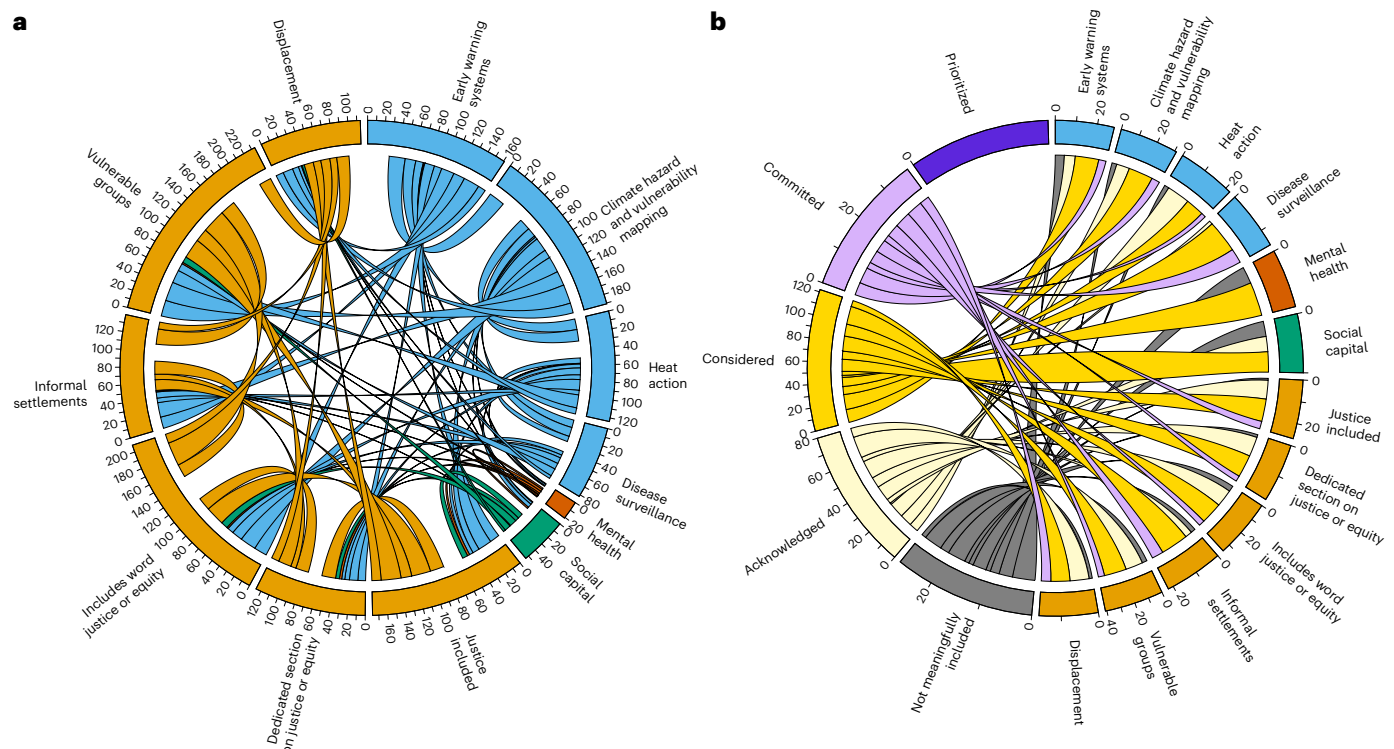
Fig. 4 | Visualizing the co-occurrence of themes in C40 adaptation plans alongside equity (a) and health prioritization level (b.) a,b, Co-occurrence of coded themes (**a**) and coded themes with health prioritization level (**b**). The outside bands show the total count of co-occurrences that the theme had across all themes. For example, early warning systems co-occurred 161 times with the themes, whereas the bands show which terms early warning systems co-occurred with. They are color coded by the thematic group. Panel **b** shows the co-occurrence of health prioritization level across each theme.

city, often from informal settlements. Only two plans acknowledged receiving displaced communities from elsewhere and included preparing for climate refugees into an action item.

We wanted to extract the relationship between health and equity in C40 adaptation planning. Figure 4a shows a co-occurrence chord diagram highlighting which plans had health and equity themes co-occurring within each plan. The figure shows unidirectional relationships from the starting theme (base color) to the end point. For example, social cohesion (green) shows that plans that had social cohesion strategies also had a section on justice or equity and discussion on vulnerable groups including mention of climate displacement.

The bands on the outside show the base color of each theme and the proportionality of that theme in our overall sample. First, looking at the outside bands, most health codes fall into either early warning systems, hazard and vulnerability mapping, or heat action. These are health-adjacent codes as all of them can be done without a health focus. Strategies that directly target a health concern (disease, mental health or social cohesion) were less common, with mental health being the least common of the three. Similarly, on the justice side (orange), the umbrella categories—vulnerable groups and overall justice inclusion—were more prevalent in the plans than specific terms such as informal settlements or climate displacement. This is expected as not all cities included here have populations living in informal settlements.

Interestingly, mental health and social cohesion rarely co-occurred with physical health indicators but did co-occur with justice. This shows that mental and social health strategies were incorporated more from an equity perspective than a health one. This is further supported compared with health prioritization categories in which mental health and social health were more common in plans that had a lower health prioritization category than the physical health indicators (Fig. 4b, purple).

Implementation readiness

We incorporated two proxy variables to gauge implementation readiness. We assessed implementability through responsibility designation and the presence of monitoring indicators. Majority of plans (62%) designated a city department that was responsible for each adaptation strategy, with some plans designating a lead agency and supporting agencies. Also, 51% of plans included indicators. However, indicators were sometimes distantly related to the adaptation strategy.

The distinction between awareness and action could be tied to time and ambition. Many of the current health adaptation strategies reflect early stages of the policy process (such as planning). This includes intention to develop future plans or to complete additional research or mapping. Funding and capacity are often cited as limiting factors to implementation and could lead to lower levels of ambition on health adaptation[13].

Further, many of the strategies listed were not granular enough for implementation. For example, many of the disease surveillance measures lacked specificity (for example, "strengthen effective climate-sensitive disease surveillance and prevention programmes"). It remains unclear how these initiatives will be implemented, what diseases will be targeted and if any implementation has occurred. Vague or broad climate adaptation strategies show a limit to operationalization. However, it is possible that these strategies would be followed up in other plans and strategies with more detail.

Moreover, the segmentation of sectors leads to challenges on planning and implementation. This was evident in the varied location of health strategies in climate plans. Plans that did not have a health section had health adaptation strategies integrated across other headings either under adaptation broadly, under social impacts, disaster management, or under vulnerability or equity subheaders. Last, the early establishment of health as a co-benefit could lead to challenges reframing and reintegrating health as a primary adaptation element.
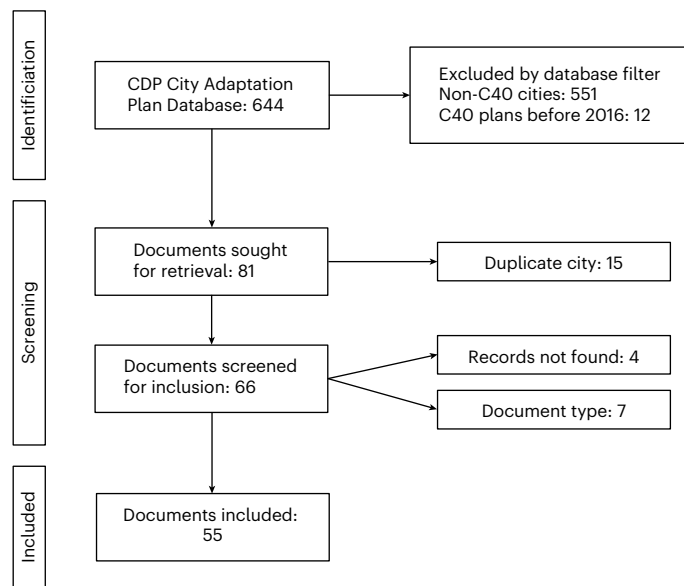
Fig. 5 | PRISMA flowchart of document inclusion. Document search and screening process utilizing Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Limitations

Our methodology does pose several limitations. First, the screening favored English-language documents. In cases where an English version was accessible online, this version was included. However, the English translation was sometimes shorter in length (that is, a summary version) or was written in simpler vernacular. If an English version was not located, Google Lens was used to translate and review the documents in English. In both cases, it is possible there is content in the original plan that was not represented in the English version or that there were errors in the translations provided.

Further, we only used one plan per city based on what was reported by cities into the CDP database. We determined that this was the most uniform method of analysis between cities, aligning with both C40's published plans[47] and similar studies[22,35]. Including additional documents from a manual search of city websites would have led to high levels of variation in information on each city and being unable to confirm the totality of the information gathered. It is possible that there are more recent plans (since August 2023) or other city planning documents that integrate elements of health adaptation, which are not included in this analysis. As CDP is self-reported, the cities are choosing the documents they determine are the most representative of their city's climate adaptation planning. There are limits to the CDP database itself. In particular, it is self-reported, which could lead to inaccuracies in the data. As all plans were reviewed manually, there was little reliance on CDP reported statistics beyond the initial sample selection.

Conclusion

When assessing a global sample of city climate adaptation plans for health and equity content, we found that C40 cities had awareness of health impacts; however, the integration of comprehensive health adaptation strategies was not prevalent. Plans that incorporated health adaptation strategies primarily had health-adjacent strategies that traverse other sectors (such as disaster risk reduction). Adaptation sections specific to the health sector or that addressed specific health outcomes (such as disease risk) were less common.

Examining health adaptation in cities by applying a biopsychosocial definition to health offers a more comprehensive approach. In this framework, we found that mental health and social health strategies were extremely rare despite climate change having profound impacts on both mental health and social cohesion. Last, we found that there was a high overlap between equity content of a plan and health content. Plans that incorporated equity included health adaptation more often.

Although we confirmed the results of previous studies that found similarly low levels of health integration in city climate adaptation, we offer a far more granular assessment of the degree to which cities incorporate physical health, mental health, social health, and justice and equity. Conceptually, we provide a more holistic analysis of health than what is common in health adaptation research. Further, we showed that in climate policy development and planning, at this stage, large cities mirror global levels of health integration in which awareness is expanding but purposeful action still lags. In this way, there is opportunity for cities to become innovative leaders on health adaptation.

As C40 cities are global leaders in climate action and all but three of our sample were megacities (population above 3 million people), we assume that this analysis is representative of other large cities globally. Our results were similar to ref. 22, whose analysis focused specifically on highly health adaptive cities. As such, it is probable that our sample may have a higher level of health adaptation than the global average.

Future research can build on this work by better understanding what role cities should take on health adaptation and work with city governments on holistic health integration. Moreover, researchers and city analysts need to go beyond the hypothetical and integrate what works not just conceptually but in practice. This study, as many others, is analyzing ambition, what cities are intending to do, but not what is being done. If implementation does not match the already lagging ambition, the gap will only grow. More research needs to think holistically and innovatively on health adaptation strategies, and those resulting strategies need more rigorously assessed for impact and effectiveness. Our study did not look at co-benefits in city climate adaptation plans, parse local adaptation on health systems using the elements of Operational Framework on Climate Resilient and Sustainable Health Systems, or assess implementation directly. Future studies could address these promising areas of research.

Research methods

To examine health inclusion in urban climate adaptation planning, we analyzed the climate action plans of cities in the C40 Cities Climate Leadership Group (C40 cities). The C40 cities are global leaders on climate policy. Previous studies that reviewed highly health adaptive cities found that health was still only minimally considered[22]. As such, focusing on the C40 cities allows for comparison across cities that might not be previously classed as having high health adaptation but that still exhibit more advanced and comprehensive climate policy. Membership to the C40 network is based on performance, with cities required to meet ambitious standards in climate policy. There are two main tiers of membership: megacity (population above three million by 2030) and innovator (smaller cities with exceptional climate leadership)[48].

We followed the search, appraisal, synthesis and analysis characteristics of a critical review[49] when building our methodology. Our search strategy aimed to identify the most relevant sample of city documents. Quality was not assessed during appraisal; however, the quality and degree of integration was a key element in document synthesis and analysis. Further, although not a requirement for critical reviews, we adhered to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines in the interest of improving the rigor and transparency of our study.

Search and appraisal: sample and search strategy

Following similar studies[35], we built our sample by identifying recent municipal climate action or climate adaptation plans for C40 cities in the most recent CDP adaptation database. Climate action plans were defined as any municipal climate planning document that focuses on climate adaptation. Climate plans were included based on the following criteria: they must be from a preidentified city, must include climate

Table 1 | Coding schematic for health prioritization levels

Level	Definition
Not meaningfully included	Does not incorporate human health considerations in a meaningful way. May mention the word "health" broadly (that is, "climate change will impact health") but neither expands on health impacts nor contains adaptation strategies specific to health.
Health acknowledged	Has a thorough background section that includes the understanding of health impacts; however, this does not translate into adaptation strategies.
Health considered	Has some health adaptation strategies most commonly on heat, disaster resilience or air pollution. These strategies are sometimes included without a strict health framing.
Health committed	Has specific, defined health interventions most commonly outside of heat and air pollution, including on health systems strengthening or disease surveillance. This is often represented in a dedicated section of adaptation strategies on health.
Health prioritized	Has a comprehensive and inclusive health adaptation section. Adaptation strategies are detailed and cover at least two biopsychosocial categories. Plan clearly demonstrates understanding of how to address health impacts and commits strongly to do so.

adaptation planning, must be in the CDP adaptation database and must be published since 2016. Here 2016 was chosen as the cut-off date to align with similar studies[22] and to exclude documents from before the Paris Agreement was signed in December 2015.

City climate adaptation plans were identified using the most recent CDP city adaptation planning database. CDP, formerly the Carbon Disclosure Project, is a non-profit global disclosure system that collects environmental data from companies, cities and countries. As such, it aims to increase transparency on the progress different entities are making toward a sustainable future. CDP has numerous publicly available datasets. We downloaded their most recent tracking of city adaptation plans, last updated in August 2023. The dataset had 644 city plans of which 93 were C40 cities (Fig. 5). An additional 12 plans were excluded for being drafted and approved before 2016.

We then located the documents for the remaining 81 plans. Plans that were not linked directly in the database were identified through a simple Internet search using Google (city name, adaptation, plan or strategy). Searches were completed in English.

To avoid duplication as well as double counting, only one plan was selected per city. For cities that had more than one climate plan in the database, the plan most likely to contain climate adaptation specific content was chosen for review. For example, if both documents contained climate adaptation strategies, the standalone adaptation plan was chosen. However, if the standalone climate adaptation plan listed was an all-hazard mitigation plan, then the combined mitigation and adaptation climate action plan was reviewed. Duplicate city documents dropped our sample from 81 to 66 documents.

Although we selected a database that focused specifically on adaptation, the documents are self-reported by cities, and seven plans did not meet our requirement of climate adaptation content. Four plans were identified as only mitigation, whereas two were hazard mitigation plans without specific climate adaptation content. Four documents were not able to be located. This reduced our sample from 66 to 55, our final number.

Synthesis and analysis: thematic content analysis
After our 55 plans, each representing one city, were collected, we conducted an in-depth content and thematic analysis. The content analysis was designed to be an abductive and iterative process, and it was done manually to avoid potential issues of bias and ethics over the use of machine learning or artificial intelligence[50]. A preliminary coding protocol was developed using the indicators in ref. 22 and a biopsychosocial definition of health. We wanted to explore city health adaptation outside of a strict health system framing, which is commonly used in adaptation literature. As such, we used a biopsychosocial approach to consider physical, mental and social health factors that could be covered in an adaptation plan[51]. The physical health indicators were based on the five commonly referenced areas of health adaptation[22,23]. The documents were coded in NVivo 14. Documents that were not in English were reviewed using Google Lens translation software and coded in NVivo in their native language.

We pretested the codes on five adaptation plans. Codes were redefined and expanded based on pretesting. Once the preliminary codes were determined, the rest of the plans were reviewed. Emerging codes were embraced and integrated into the coding scheme. Plans were iteratively reviewed to ensure homogeneity and only adaptation sections of plans were reviewed. The final coding scheme included 13 codes across physical health, mental health, social health, equity and justice, and implementation. If health adaptation strategies were found outside of these codes (that is, health system strengthening), they were put under "physical health" and are included in our analysis. Additionally, each plan was given a health prioritization category (Table 1) depending on the level of health integration throughout the plan. The full coding scheme can be viewed in Supplementary Material 1. Document coding was conducted by one author (DO) to ensure consistency. Results were verified by both authors. The data were extracted into an Excel file, cleaned and analyzed. Figures were made in R. The chord diagrams were made in Circos[52].

Reporting summary
Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability
The adaptation plans and CDP dataset used in this study are publicly available. The CDP dataset can be accessed from https://data.cdp.net/Adaptation-Actions/2022-Cities-Adaptation-Plans/iwt3-42qn/about_data. The qualitative coding summary is available via Zenodo at https://doi.org/10.5281/zenodo.17418473 (ref. 53).

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Author contributions

D.O. and B.K.S. conceptualized the work. D.O. carried out the methodology, interpretation of results and original draft writing. B.K.S. critically reviewed and edited the manuscript and supervised the research.

Competing interests

The authors declare no competing interests.

Additional information

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Extended Data Table 1 | Examples of physical health inclusion in plans

Physical health area	Specific examples from city plans
Early warning systems	"Establish early warning system for climate risks" (Seoul) "Build resilience and preparedness against flood incidents through early warning systems and disaster response plans" (Kuala Lumpur) "Develop and implement an early-warning and real-time monitoring system for heat" (Cape Town) "Building an early warning system for flooding-related infectious diseases caused by climate change in HCMC. [..] Developing human resources and improving capacity of commune-level medical staff for health care demand before, during and after natural disasters. Developing assessment methods for community scale flood-related health risks and an early warning system for flood-related infectious diseases in HCMC." (Ho Chi Minh City)
Hazard and vulnerability mapping	"A full risk assessment should be undertaken to map the exposure, vulnerability and adaptation capacity of priority hazard" (Quezon City) "The Department of Public Health developed the Climate and Health Program to develop solutions to support healthy and climate-ready communities. The Program has produced vulnerability assessments on heat and flooding and developed education and outreach materials." (San Francisco)
Heat action	"Train and amend working schedule for maintenance officials to cope with hot working conditions." (Addis Ababa) "Review the Action Plan for Preventing the Effects of Heat Waves on Health" (Barcelona) "Identify existing and potential climate shelter spaces: public and private facilities and public spaces (e.g. parks and gardens) which could provide conditions for thermal comfort in extreme episodes and establish the services linked to the heat wave action protocols that these spaces need to offer, aside from quantifying the extra resources required (parks open 24 hours, use of "greened" school playgrounds, block interiors, etc.). Map the degree of cover to ensure territorial fairness and take into account the areas identified as the most vulnerable to heat." (Barcelona) "Conduct an awareness-raising campaign to educate citizens on how to remain cool during a heat wave." (Johannesburg) "Organize capacity building of health workers in identifying and treating heat-related illness." (Mumbai) "Reduce the heat-island effect and related increase in outside air temperatures with cool and living roofs, expanded green space, tree planting, and tree protection efforts, prioritizing hotspots and those areas with the greatest number of heat vulnerable residents." (Washington DC)
Disease surveillance	"Adapt municipal protocols and mechanisms to anticipate, detect and control the emergence of new vectors of disease transmission" (Madrid) "Improve climate-sensitive diseases control programmes" (Dar es Salaam) "Reduce the risk of infectious disease outbreak by providing information on the occurrence of mosquito-borne infectious diseases, infection prevention measures, and appropriate measures to control mosquito sources. Conduct surveillance of mosquitoes, which transmit infectious diseases, and ensure an inspection system for pathogens." (Tokyo)
Other categories Air pollution	"Conduct a health risk assessment through an extensive survey to identify the community exposed to air pollution-related activities and vulnerable to the corresponding health issues." (Mumbai) "Protection of vulnerable populations from air pollution ~ Air pollution monitoring and prevention" (Seoul) "Reduce air pollutants by 2030 to improve air quality and lower the rate of respiratory disease." (Barcelona)
Health systems	"Building climate-resilient health systems for all. Percentage of the population with access to health infrastructure (Basti Clinic) Percentage of the population with access to information on the impact of climate change on human health" (Chennai) "Enhance capacity of the public health care systems to respond to climate change-related health risks" (Dar es Salaam) "Develop an integrated climate and health research agenda for eThekwini Municipality, focusing on: Identifying and profiling the risk and needs of the most vulnerable population groups; and Determining and quantifying the types, nature, magnitude distribution of current and potential health impacts" (Durban) "DINKES is charged to increase overall healthcare provisions by growing both the number of primary service facilities (permanent but also temporary during climate events) and the number of staff, especially in rural areas that have the highest incidences. Healthcare providers will be provided with additional training on health issues related to climate hazards." (Jakarta)

This table provides descriptive examples of physical health strategies from the city climate action plans.

Extended Data Table 2 | Examples of mental health inclusion in plans

Mental health area	Specific examples from city plans
Emergency response	"Train more first responders and service providers in psychological first aid. Psychological first aid is a supportive intervention used in the immediate aftermath of disasters and terrorism. By increasing psychological first aid training to emergency personnel and service providers, these professionals with have another set of tools to assist Houstonians and will have additional support to improve their own mental/behavioral health." (Houston) "Ensure that mental health is considered in climate change response and that it is addressed in the implementation of projects and programmes where possible" (Cape Town) "Ensure that communication and messaging related to climate change is sensitive to mental health concerns and does not exacerbate feelings of anxiety or despair" (Cape Town)

This table provides descriptive examples of mental health strategies from the city climate action plans.

Extended Data Table 3 | Examples of social inclusion in plans

Social capital area	Specific examples from city plans
Community cohesion	"Measure and support the development of Montrealers' social capital Montréal will seek to better understand the social capital of its community by collaborating more closely with the Direction régionale de la santé publique of Montréal and several local partners. The city will first study the social conditions of older people in Montréal, followed by a second study of the social capital of the population aged 18 and over. These studies will illustrate the strength of social ties in districts, along with interventions that can counter isolation and favour a sense of security and solidarity between individuals. A detailed portrait, produced every five years, will serve as an indicator of community resilience to climate, environmental and public health issues, to allow the city to better respond to urban safety challenges and to measure the well-being of the population." (Montréal) "Invest in local arts and culture to build community cohesion and to celebrate neighborhood identity." (Houston) "Empower people and partnerships to reduce vulnerability and promote resilience at the building, block, and neighborhood level." (San Francisco)
Support networks	"Improve the social network of elderly people who live alone and reinforce existing projects (vincles, radars, etc.) and specific actions on vulnerable groups in the teleassistance service." (Barcelona) "Neighborhood Resilience Hubs are physical spaces, hosted within trusted spaces in neighborhoods, that facilitate social, climate, and economic resilience along with disaster preparedness. In times of disruption and disaster, Hubs can facilitate emergency response and recovery by providing a safe place of refuge with emergency supplies, communication tools, and recovery support and services." (Houston) "The city will be recognized for promoting healthy ageing, fostering intergenerational integration and sociability of the elderly population." (Rio de Janeiro)
Other: social determinants of health	"Inductive economic activities will have an expanded presence in the city, contributing to reduce inequality of access to employment opportunities." (Rio de Janeiro) "Strong, resilient communities have easy access to essential services, like food, water, medical care, and vibrant social networks that enable neighbors to help one another. Through neighborhood planning and investments, we will develop and maintain neighborhoods with a diverse mix of services, housing, and transportation options." (Washington DC) "Rio's citizens will have the opportunity to sports and culture as a means of developing citizenship and ethical values, enhancing the economy of culture, access to sports practice and cultural territory for all." (Rio de Janeiro) "Provide grants and subsidies for housing energy improvements and prioritise work on the homes of families in vulnerable situations and at risk of social exclusion" (Barcelona)

This table provides descriptive examples of social health strategies from the city climate action plans.

Extended Data Table 4 | Examples of justice and equity inclusion in plans

Equity area	Specific examples from city plans
Justice or equity	"Climate change already disproportionally affects poor and vulnerable populations. Climate action is therefore not only an environmental issue, but also a social justice imperative, inextricably linked to challenges such as eradicating poverty and enhancing inclusivity." (Johannesburg) "The metropolitan climate adaptation should promote a spatial development which assures social and territorial cohesion, reducing inequalities and acting foremost on increasing the resilience of the most vulnerable individuals and communities, more exposed and susceptible to climate risks and with less adaptive capacity." (Lisbon) "Effective climate action furthers climate justice and reduces social vulnerability, and enhances populations' health, safety and prosperity." (Tshwane) "Our most vulnerable residents should not only bounce back after disasters, but bounce forward. This fundamental principle is echoed by our Sustainable DC goals to advance equity and diversity. To ensure the goal of providing equitable access to services, resources, and economic opportunities remains at the forefront of this and future initiatives, DOEE will convene a group of diverse community stakeholders and city leaders to guide the equitable implementation of Climate Ready DC." (Washington DC)
Vulnerable populations	"Thus, the fisherfolk – in view of their linkage to the coast for their living (housing) as well as livelihood (employment source) – are among those most vulnerable to [sea level rise]. The impact of [the urban heat island] effect, as discussed above, is also more critical on the urban poor communities, driven by their inability to afford air conditioning; avoid strenuous activities; or avail of proper roofing material, shades, or protection." (Chennai) "The situation is exacerbated by other vulnerabilities such as job insecurity, job informality, frequent displacement, migration, and lack of social safety nets to fall back on in times of crisis. Thus, due to higher exposure to hazards as well lower capacities to cope with climate induced events, the urban poor face higher vulnerabilities. Within the community, women are doubly marginalised, as they face multiple layers of discrimination over access to basic services and livelihoods." (Chennai) "Those who are more exposed, less able to regulate their body temperatures, or less able to move to cooler places are also at risk. Socially isolated people with physical or mental limitations are also less likely to have a support network available for help during a heat episode.[...] 'At risk' and 'disadvantaged' groups, care homes, schools and hospitals (including rough sleepers and the hidden homeless) will be prioritised." (London)
Informal settlements	"Flooding in Addis Ababa is particularly linked to rapid urbanisation, the location of poor quality housing and informal settlements in flood-prone areas, poor drainage, lack of solid waste collection, and loss of greenspace" (Addis Ababa) "Chennai will work towards rehabilitation of vulnerable populations living within flood risk zones, retrofitting existing slum housing for heat resilience and decentralised health infrastructure as part of its vision of 'climate proofing for all.'" (Chennai)
Displacement	"Plan for climate-related migration: assess potential impacts of climate change scenarios on Auckland's population, and establish targeted programmes for affected communities and individuals to support climate migrants and the current needs of our growing population." (Auckland) "Sea level rising and coastal erosion threaten beaches and may result in the displacement of populations and infrastructure along the coast." (Dakar)

This table provides descriptive examples on how justice and equity was included in city climate action plans.

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Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	No software was used
Data analysis	NVivo 14; R version 4.4.1 and Circos 0.69-9 were used in the data analysis

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The original dataset was accessed here https://data.cdp.net/Adaptation-Actions/2022-Cities-Adaptation-Plans/iwt3-42qn/about_data and downloaded on 17 November 2024. All documents screened are publicly available.

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Behavioural & social sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	The study is a qualitative study using document analysis (critical review)
Research sample	The sample is 55 city climate action plans
Sampling strategy	Our sample was determined by our inclusion criteria. We started with the most recent CDP City Climate Adaptation Plans database. City plans were included if they were from a C40 city, were published since 2016, were publicly accessible, and contained a section on climate adaptation. This strategy was selected as it aligned with similar studies (ie Sheehan et al 2022; Diezmartínez & Short Gianotti, 2022) while selecting for a larger global sample for a more comprehensive review.
Data collection	Documents were downloaded into NVivo and were coded using an abductive coding scheme. Document coding was simultaneously tracked in Excel.
Timing	The original dataset was downloaded on November 11 2024. The document review and analysis was conducted between January and March 2025. Six additional documents were added to the sample and reviewed in June 2025.
Data exclusions	Exclusion criteria was pre-established. 551 documents were excluded for not being a C40 city, 12 were excluded by date (published prior to 2016), 15 were excluded for duplicates, 4 were unable to be located, and 7 didn't meet our required document type. 2016 was chosen as the cut-off date to align with similar studies and to exclude documents from before the Paris Agreement was signed in December 2015. To avoid duplication as well as double counting, only one plan was selected per city.
Non-participation	N/A
Randomization	N/A

Reporting for specific materials, systems and methods

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☒	Animals and other organisms
☒	Clinical data
☒	Dual use research of concern
☒	Plants

Methods

n/a	Involved in the study
☒	ChIP-seq
☒	Flow cytometry
☒	MRI-based neuroimaging

Plants

Seed stocks	N/A
Novel plant genotypes	N/A
Authentication	N/A