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Need for considering urban climate change factors on stroke, neurodegenerative diseases, and mood disorders studies

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Abstract

The adverse health impacts of climate change have been well documented. It is increasingly apparent that the impacts are disproportionately higher in urban populations, especially underserved communities. Studies have linked urbanization and air pollution with health impacts, but the exacerbating role of urban heat islands (UHI) in the context of neurodegenerative diseases has not been well addressed. The complex interplay between climate change, local urban air pollution, urbanization, and a rising population in cities has led to the byproduct of increased heat stress in urban areas. Some urban neighborhoods with poor infrastructure can have excessive heat even after sunset, increasing internal body temperature and leading to hyperthermic conditions. Such conditions can put individuals at higher risk of stroke by creating a persistent neuroinflammatory state, including, in some instances, Alzheimer's Disease (AD) phenotypes. Components of the AD phenotype, such as amyloid beta plaques, can disrupt long-term potentiation (LTP) and long-term depression (LTD), which can negatively alter the mesolimbic function and thus contribute to the pathogenesis of mood disorders. Furthermore, although a link has not previously been established between heat and Parkinson's Disease (PD), it can be postulated that neuroinflammation and cell death can contribute to mitochondrial dysfunction and thus lead to Lewy Body formation, which is a hallmark of PD. Such postulations are currently being presented in the emerging field of 'neurourbanism'. This study highlights that: (i) the impact of urban climate, air pollution and urbanization on the pathogenesis of neurodegenerative diseases and mood disorders is an area that needs further investigation; (ii) urban climate- health studies need to consider the heterogeneity in the urban environment and the impact it has on the UHI. In that, a clear need exists to go beyond the use of airport-based representative climate data to a consideration of more spatially explicit, high-resolution environmental datasets for such health studies, especially as they pertain to the development of locally-relevant climate adaptive health solutions. Recent advances in the development of super-resolution (downscaled climate) datasets using computational tools such as convolution neural networks (CNNs) and other machine learning approaches, as well as the emergence of urban field labs that generate spatially explicit temperature and other environmental datasets across different city neighborhoods, will continue to become important. Future climate – health studies need to develop strategies to benefit from such urban climate datasets that can aid the creation of localized, effective public health assessments and solutions.

Keywords Urban heat island, Climate change, Neuropathologies, Neurodegenerative diseases, Neuroinflammation, Urban climate, Bioclimatology

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1 Introduction

Cities pose an important challenge for climate–health impact studies because of the high environmental exposures, population density and notable diversity in the neighborhoods. While many climate–health impact studies have emerged, the role of urban heat islands (UHI) and the variability in the UHI *within city neighborhoods*are still poorly understood. In the classical sense, UHI results from the temperature (heat) differences between urban areas, which are generally warmer than surrounding suburban and rural areas (Oke, 1979; Mills et al. 2022). The temperature extremes in urban areas and their spatio-temporal patterns are associated with meteorological and urban surface drivers (Liang et al. 2018; Tewari et al. 2019; Mills et al. 2022). Weather and climate conditions interact with urban surface properties to manifest the variability in environmental/climatic and biogeochemical conditions across the cities. The modulation by these processes is complex, and their interacting effect on human health associated with heat risk is important to consider. This is because, out of the global population of 7.6 billion in 2018 the urban population was 4.2 billion (UN, 2018); by 2050, the global population will reach 9.7 billion. A staggering 68% of the population (i.e., 6.6 billion people) will live in urban areas (Sun et al., 2020). The interaction of climate change, urbanization, and an increasingly growing population in cities put the very young and the aging population living in those areas at higher health-related risks due to heat stress compared to those living in rural or suburban areas (Varquez et al., 2020). Additionally, vulnerable social groups living in these highly urbanized regions are at higher health risk (de Snyder et al., 2011). For example, the human body can typically adapt to extremes of dry bulb temperatures if the wet bulb temperature is below a threshold of 35 °C (Pal & Eltahir, 2016). Extreme temperatures due to global warming affect normal thermoregulation and can impact human health (Ahima, 2020). The coastal urban regions, which are expected to have a higher population by the mid to end of the century, are particularly vulnerable to facing similar environmental conditions where extreme heat can occur (Cianconi et al., 2020).

The emergence of cities as social hubs that have exaggerated environmental loading has made it imperative to understand the intricate interplay between surroundings and its physiological impact on the human mind; additionally, it is crucial to integrate climate change into urban development (Ancora et al., 2022; Ye & Niyogi, 2022). Recent studies have drawn attention to an emerging discipline called neurourbanism (Adli et al., 2017; Pykett et al., 2020; Mondschein & Moga, 2018). Indeed, neurourbanism as a field examines the theoretical perspectives and analytical methods of both basic and clinical neuroscience, and provides insight into urban planning and design practice, such as understanding how the impacts of urbanization and urban heat impact environmental prosperity and community construction. Neurourbanism helps link urbanization and neuroscience. In doing so, it is possible to develop novel ideas and analytical methods that can aid the creation of better city (built or natural) environments. Such integration can eventually improve the mental and physical wellbeing of individuals and communities by making cities both climate resilient and more livable.

The novel nature of neurourbanism as a field of study necessitates further insights to bridge the current research gaps. Furthermore, establishing a relationship to urban health and impacts on neuropathological conditions will drive the field of neurourbanism towards a more comprehensive picture of the urban environment and neuroscience as a whole. Thus, in this article, we seek to: (i) expand on the terminologies that emerge in the urban climate–health literature; (ii) highlight the role and need for considering within-city variability rather than only using regional temperature or UHI for studying health impact studies; and (iii) clarify how the increase in urban population, urban air pollution, and increase in temperature due to both climate change and urbanization can affect stroke, neurodegenerative diseases, and mood disorders - and the need for explicit consideration of urban climate in neurourban studies.

2 Urban impacts on climate and neuropathological diseases

In this section, we outline the following six aspects: (i) urban climate variability, (ii) urban heat island variability, (iii) pathological effects of urban warming on stroke, (iv) hyperthermia and onset of neurodegenerative or mood disorders, (v) urban effects on mood disorders, and (vi) empirical link between hypothermia and neuropathology.

2.1 Urban climate variables and variability

Many health impact studies consider terminologies such as heat stress that corresponds to analyzing link with air temperature, as well as surface temperature, dew point, barometric pressure, and relative humidity as urban climate variables. For example, Qi et al. (2020) and Zaręba et al. (2021) showed the influence of some of these parameters on stroke. However, the impact of climate change and its consequences on mental health does not have a clear conclusion. One of the reasons for this is the heterogeneity in urban environments and also in the type of measurements (such as air temperature, urban canopy temperature, skin temperature, wind speed and directions at different vertical levels). The impact of urban climate on mental health can occur in the short and long term on a varied, diverse population. The use of air-temperature, 2 m temperature, skin temperature or urban canopy temperature (Mills et al., 2022) further adds to the list of complexities as they are quite different from each other. Still, the broader community does not well consider that difference.

In urban environments, it becomes increasingly difficult to estimate temperature because of the lack of urban datasets and often 2 m-temperature airport data is often used as a measure of temperature even in the urban environment. Also, urban canopy temperature estimations differ in urban areas (compared to 2 m-temperature), where additional consideration of the canopy layer needs to be made. In many instances, surface temperature (which is essentially the skin temperature) from satellite data products are used because of their ready availability. However, for various purposes, it could lead to wrong conclusions; hence, care must be taken while using these satellite products as urban temperature. Surface (road) temperature and surface air temperature can be different by several degrees (Faghih Mirzaei et al., 2015).

Daily weather conditions for an entire city are usually represented by a station generally located close to a nearby airport. Such datasets typically fail to capture the microscale climate variability associated with urbanization. For example, Hass et al. (2016) used heat index (a combination of temperature and humidity) to assess the variability of heat exposure across four urban neighborhoods and two control locations in Knoxville, Tennessee, USA. Studies (e.g., Wang et al., 2021) have also found that prolonged exposure to high levels of particulate matter with a diameter $\leq 2.5\,\mu m$ ($PM_{2.5}$) could increase the risk of neurological disorders, such as Alzheimer's disease (AD) and Parkinson's disease (PD). Urban pollution measurements and efforts to reduce it can help decrease the burden of age-related neurodegenerative disorders as discussed in Crouss-Bou et al. (2020). It is important to consider that pollutant loading is intricately linked to the local-scale urban meteorological considerations. Thus, specificity in the data (variables) being used, the location of the measurements or data collection and variability within urban regions need to be explicitly reported (and considered) when conducting urban health studies.

2.2 Consideration of temperature, wind and humidity in urban heat variability

Variation in urban heat is linked to temperature but it is important to recognize the vital role of humidity as well. These variables, along with wind, contribute to thermal comfort or stress. In Fig. 1a and b, we show temperature and humidity variation for 12 automated weather (Metar) stations in the New York region for December 2015. The air temperature and humidity at these stations vary considerably, with the mean temperature variation in the range of 7–12 °C along with mean humidity variation in the range of 60–85%. Further analysis (Tewari et al., 2016) presented in Fig.1c and d shows that JFK airport is warm and moist relative to LaGuardia airport. Thus, based on this analysis, LaGuardia would be more comfortable (in terms of heat stress) compared to places near JFK airport. We used a Weather Research and Forecast model (WRF model) and performed 2 nested domains (15 km and 3 km) simulations starting 15 July 2006, 1200UTC till 6 Aug 2006, 1200UTC (for details regarding model domain and configuration, refer Tewari et al. (2019)).

As shown in Fig. 2a and b the air temperature when extracted from 15 km (Fig. 2b) resolution model output at two locations JFK airport and LaGuardia airport which are about 15 miles apart, show less variation compared to the 3 km horizontal model grid spacing output (Fig. 2a). This highlights the need for high-resolution spatio-temporal information to properly assess realistic temperature impact on health.

Although there has been some recent discussion regarding the impact of climate change on various neurodegenerative diseases (Bongioanni et al., 2021; Ruszkiewicz et al., 2019), how the complex interaction between urbanization, urban air pollution, and climate change affects neurological developments is an area that needs further attention. Specifically, the UHI phenomenon as part of urbanization, in conjunction with urban climate and urban air pollution, has not been examined regarding the disproportionate impact of neuropathologies on underserved communities. The link between climate change and maladaptive pathophysiological developments is twofold; first, rising temperatures can lead to the worsening of neurodegenerative diseases (Zammit et al., 2021) and stroke (Habibi et al., 2014). Second, increases in temperature in urban areas foster an environment where individuals may be at higher risk for the development of various neurological diseases by being in a consistent inflammatory state. Due to the heterogeneous urban environment and the spatial variability in temperature, it is often reported that the underserved populations living in these urban areas have disproportionately higher exposure (Scotland et al., 2023). To fully understand these impacts, there is a need for enhanced long-term urban-scale datasets.

2.3 Pathological effects of a warming climate on stroke

In this section, we highlight some studies that show that urban heating can increase the risk associated with stroke. An increase in land surface temperatures has been noted to correlate with strokes and neurodegenerative disorders (Habibi et al., 2014). It has also been postulated that a hot climate, or more generally,

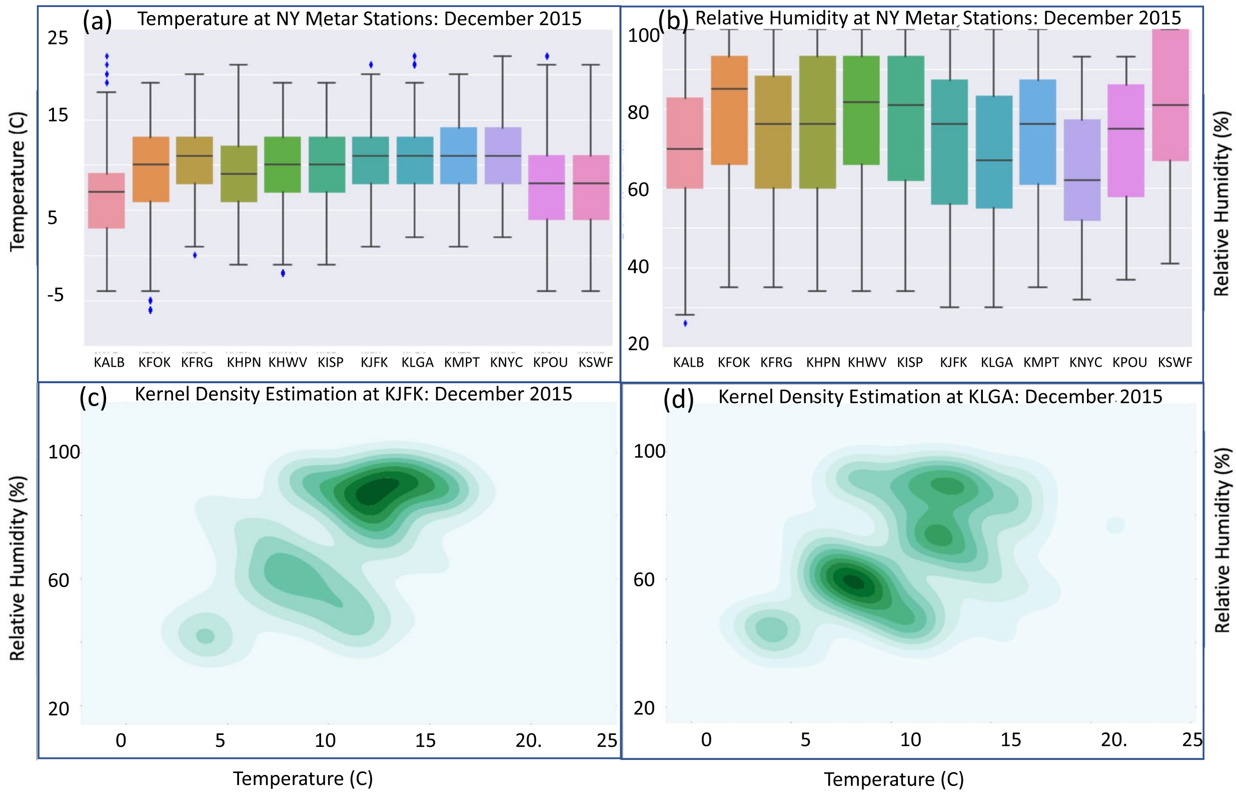

Fig. 1 **a** Air temperature at New York metar stations for December 2015 (KALB = Albany; KFOK=West Hampton Beach, NY; KHWV=Brookhaven, NY; KFRG = Farmingdale, NY; KHPN=White Plains, NY; KISP=ISLIP, NY; KJFK = JFK Airport, NY; KLGA = LaGuardia Airport, NY; KMTP = Montauk, NY; KNYC = Central Park, NY; Poughkeepsie, NY; KSWH = Newburgh/Stewart, NY). **b** Relative humidity at the same metar stations for December 2015, **c** Kernel density estimation at JFK airport for December 2015 and **d** Kernel density estimation at LaGuardia airport for December 2015

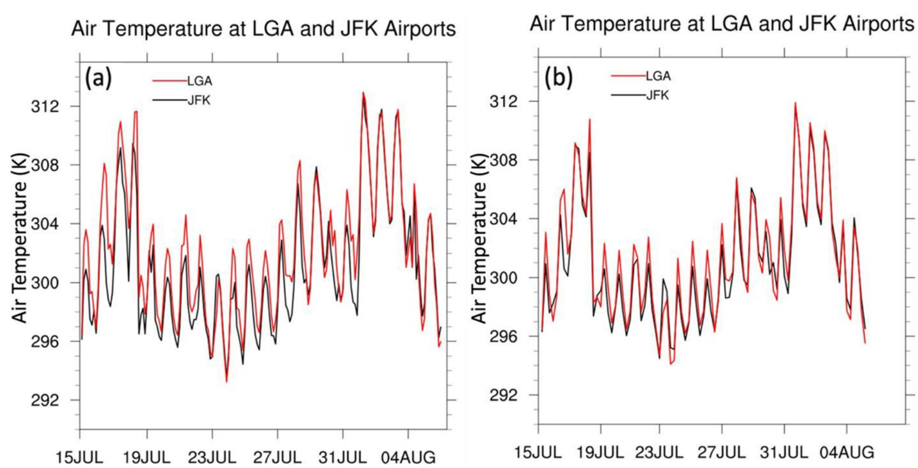

Fig. 2 **a** 2 m-air temperature at JFK airport (black line) and LaGuardia airport (red line) from WRF model simulations at 3 km grid spacing (**b**) Same as (**a**) but for 15 km grid spacing. The time series is from 15 July 2006 to 6 Aug 2006

an increase in temperatures, can lead to hyperthermia (Lee et al., 2011). Although relatively elevated body temperatures, up to 39 °C, are known to enhance action potential conduction and promote appropriate neurotransmitter release (Habibi et al., 2014), hyperthermic (40.6–41.7 °C) conditions create a potentially hazardous situation (Hsu et al., 2011; Favero-Filho et al., 2008). It is also well known that both during and after a stroke, brain temperature is elevated (Habibi et al., 2014). This highlights a link between hyperthermia and strokes; elevated brain temperatures exist during the onset of a stroke (and after the stroke as well), indicating that necrotic damage to the brain releases heat. This is likely due to an increased metabolic rate and the release of free radicals (Habibi et al., 2014). It is expected that heat itself could be the causative agent predisposing an individual to stroke. Heat can induce apoptosis (Shultz & Maslin, 2013; Katschinski, 2004) and necrosis Katschinski, (2004). Cells undergoing cellular death can release damage-associated molecular patterns (DAMPs), leading to a downstream pathway in which inflammatory cytokines are released. This can lead to neuroinflammation, putting an individual at risk for neuropathological conditions such as stroke. Considering heat is also a byproduct of stroke, the relation between heat and stroke continues to be synergistically important for future urban climate studies. Stroke produces hyperthermic conditions in the brain, and higher external temperatures can induce neurological hyperthermia, which, through the pathways of inflammation, free radicals, and cell death, can lead to the onset of stroke.

2.4 Contribution of hyperthermic conditions on the onset of neurodegenerative and mood disorders

Apart from its role in the cyclic pathogenesis of stroke, hyperthermia has also been purported to exacerbate the formation of amyloid beta plaques and increase the number of phosphorylated tau proteins (Sinigaglia-Coimbra et al., 2002). Although the potential for environmental pollutants as risk factors for neurodegenerative diseases such as Alzheimer's Disease (AD) has been noted (Chin-Chan et al., 2015), the implication of climate change and urban heating adds a new dimension to the discussion of neuropathologies. Tau protein phosphorylation leading to neurofibrillary tangles, in conjunction with the increase in amyloid beta production, indicates that hyperthermic in-vivo conditions can lead to a phenotype reminiscent of Alzheimer's Disease (AD). Amyloid beta plaques, specifically, can disrupt the trafficking of post-synaptic glutamate receptors. This disruption can lead to impaired long-term potentiation (LTP) and long-term depression (LTD). An impairment of these specific activities can also alter the hippocampal function and negatively affect the mesolimbic pathway. Mesolimbic pathway dysfunction can lead to psychological disorders like mood disorders (Russo & Nestler, 2013). This indicates that, along with inducing an AD-like phenotype, elevated temperatures can lead to other neurodegenerative diseases and mood disorders, such as depression, anxiety, and bipolar disorder. The possibility of psychiatric illness due to urbanization has been previously postulated (Lambert et al., 2015). However, the mechanism seems to be implicated in mesolimbic pathway dysfunction; because hyperthermia is potentially involved in this dysfunction, it will be imperative to consider the influence of urban heat on this phenomenon.

Although no direct evidence indicates that hyperthermia leads to Parkinson's Disease (PD) (Zammit et al., 2021), a plausible link between the pathological effects of hyperthermia and PD is postulated. Free radicals and reactive oxygen species (ROS), as byproducts of hyperthermia-induced cell death, lead to neuroinflammation. Free radical damage is known to impair mitochondrial functions, leading to Cytochrome C release through the permeability transition (PT) pore, the caspase cascade, and widespread cell death. This increases the free radicals present and only exacerbates the inflammatory state. Oxidative damage also leads to alpha-synuclein aggregation, which is a hallmark of PD (Kumar et al., 2012). Alpha-synuclein protein leads to Lewy Body formation, a precursor to cell death. Specifically, the death of neurons in the nigrostriatal pathway leads to the PD phenotype. Thus, because hyperthermic conditions can lead to neuroinflammation, it is likely that hyperthermia, induced through urban overheating, can play a role in the pathogenesis of PD.

2.5 Significance of urban environments on mood disorders

An unintended consequence of urban environments is detachment from nature and associated experiences. Studies (Bratman et al., 2015) indicate that experiences, such as a 90-min nature walk, reduced rumination and subgenual prefrontal cortex (sgPFC) activation significantly more than walks in urban settings. The study also notes that the sgPFC has been linked to self-focused behavioral withdrawal, which has been linked to rumination in depressive and healthy individuals. Additionally, rumination has been associated with a higher risk for depression. Therefore, the finding that nature walks reduce the effects of potential mood disorders, the onset of these symptoms could be linked to urban environments through mesolimbic pathway dysfunction through mechanisms described above. However, this would require further experimentation.

The implication that urban environments, in conjunction with a warming climate, can potentially lead to the onset of mood disorders and other psychiatric illnesses through mesolimbic pathway dysfunction is substantial. For example, Rodriguez-Loureiro et al. (2022), in their study of long-term greenness and neurodegenerative disease mortality among older adults, showed that the

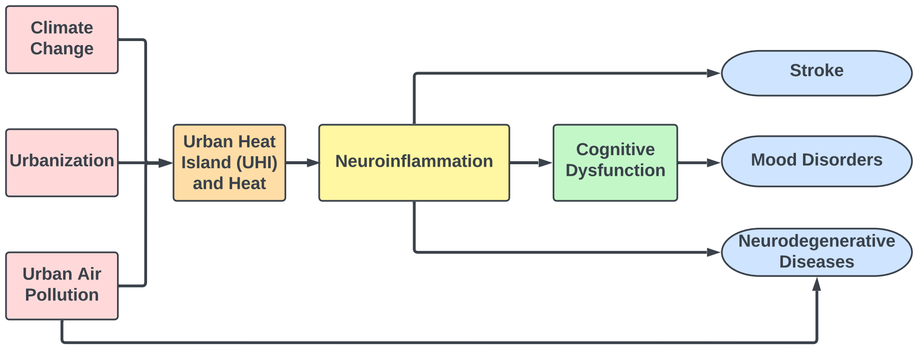

Fig. 3 Potential pathways linking climate change, urbanization, and urban air pollution to neuropathological conditions

risk of neurodegenerative disease mortality among older adults is reduced by living near greener spaces that are potentially independent of air pollution. A significant beneficial effect may be noticed among the socioeconomically disadvantaged groups- making an important case for enhancing green cover in socially vulnerable urban neighborhoods. Their results highlight the importance of the living environment to promote healthy aging and reduce the burden of neurodegenerative diseases, especially among the most vulnerable populations. The authors found a 2% reduction (per 0.14 increase) in neurodegenerative disease mortality with surrounding greenness. There is a need for additional research to confirm these findings in different settings to explore other underlying mechanisms linking the surrounding green cover to neurodegenerative diseases.

2.6 Empirical data evidence linking hyperthermic conditions with neuropathologies

Hyperthermia-induced effects on neuropathologies have been noted previously. Specifically, the effect of hyperthermia on cognitive impairment has been recently explored (Taylor et al., 2016). In past studies, decreased cognitive activity was reported through EEG analysis (de Labra et al., 2021), in which the authors reported a 24% decrease in EEG amplitude in 2–3 months old female mice when the temperature was increased from 37 °C to 42 °C. Chronic cognitive dysfunction can lead to cognitive impairment; specifically, cognitive changes have been noted in neuropsychiatric illnesses such as mood disorders (Miskowiak & Petersen, 2019). This finding aids in establishing the link between cognitive dysfunction and mood disorders (Fig.3).

Studies have also noted cognitive alterations due to hyperthermic conditions (Gaoua et al., 2012; Lenzuni et al., 2014). Gaoua et al. (2012) found that elevation of skin temperature by 3 °C led to a decrease in task planning accuracy and that participants took 41% longer to indicate the correct response. Lenzuni et al. found that upon raising the temperature by 0.3 °C, participants' cognitive function on both simple and complex tasks were impaired by approximately 50%. These are important factors when considering the cooling potential possible by greening or other adaptive measures in urban neighborhoods.

The hyperthermic effects on psychiatric illnesses indicated above show a strong potential for heat as a important factor in the onset of neuropsychiatric illnesses. A meta-analysis of data from 1966 to 2006 (Medline) and 1982–2006 (CINHAL) found that these neuropsychiatric illnesses tripled the risk of death and were correlated strongly with mortality during heatwaves (Odds Ratio (OR), 3.61, 95% CI, 1.3–9.8) (Bouchama et al., 2007). The interaction of urban heat with heat waves exaggerates the impact. For example, Hansen et al. (2008) noted that using health outcome data from Adelaide, South Australia, between 1993 and 2006, hospital admissions increased by 7.3% during heat waves compared to non-heat-wave periods. The illnesses for which these admissions increased included mood and mental disorders. Heat seems to be a risk factor for those already with mood disorders. Thus, through the mechanisms described above, heat may also contribute to the onset of these disorders.

3 Future outlook

3.1 Beyond animal models, climate models, and need for urban climate studies

Neurodegeneration due to hyperthermia has been linked to oxidative stress (Violet et al., 2014). Oxidative stress is known to be a fundamental component of neuroinflammation, which can lead to stroke, neurodegenerative diseases, and mood disorders. Thus, experimental findings that support that hyperthermia contributes to oxidative damage provide evidence for the link between hyperthermia and stroke, neurodegenerative diseases, and mood disorders. Furthermore, Chauderlier et al. (2017) found that, in mice, hyperthermic conditions (44 °C), hyperthermic stress induces noncytotoxic oxidative damage, which was noted through protein carbonyl groups that are known to be biomarkers of oxidative stress.

The analysis of factors such as climate change and urbanization on neuropathologies have been examined primarily through animal models. However, this is a problem that is being exacerbated by the effects of climate change; thus, it is imperative to garner insights regarding human disease patterns to obtain clarity on the impact on social vulnerability as well. In addition to the experimentation performed by Bratman et al. using human models, additional case studies to examine the effects of urbanization and climate change as it relates to hyperthermia would be needed to observe pathogenesis in individuals that previously lived in a cool urban climate and then exposed to hotter urban climates. This would provide additional evidence of hyperthermic conditions and how it relates to climate change-induced hyperthermia in highly urbanized areas.

3.2 Need for urban climate datasets

For urban planning, urban climate application and their combined impact on human health, it is becoming apparent that detailed, spatially explicit urban datasets are needed. However, the data from climate models are available at 50-100 km horizontal resolution, which does not represent the urban scale processes, and within city variations. Furthermore, while regional and global climate projections are used for cities, the proper representation of urbanization and feedback within these models remains a major knowledge gap. Therefore, efforts to represent urban-scale processes in climate models should be addressed. These advanced climate models with proper representation of urban-scale processes will be necessary for understanding the human-centered urban climate interaction and its impact on human health and the value of neurourban studies.

Current efforts are underway for satellite-based approach to extract 3D urban morphology information and then retrieve and validate typical urban morphological parameters for urban climatic applications (Kamath et al., 2022). Such studies in addition to the World Urban Database and Access Portal Tools (WUDAPT) products help provide 2D urban form data for cities worldwide. Newer machine learning based approaches and other novel methods can quickly and efficiently produce high spatiotemporal datasets (Fung et al., 2022; Zhang et al., 2022) accurate 3D urban morphology data for cities where actual urban morphology data are not accessible. When incorporated in the next-generation urban-climate models, such datasets can help understand the role of urban climate in human health studies.

4 Conclusions

Assessments in neurourban studies show that increase in ambient temperatures can lead to hyperthermic conditions in the body. In such situations, vulnerable communities can become more prone to inflammatory conditions through cell death, free radical production, and mitochondrial dysfunction. A factor to consider is that the warming due to climate change and urbanization can amplify these vulnerabilities. Higher vulnerabilities to heat stress are typically in urban areas with less vegetation cover, higher impervious surface and anthropogenic activity. Because urban areas have heterogeneous temperature patterns, the increases in some regions can make individuals in those locations much more susceptible to increasing temperatures and hyperthermic body conditions. Urban settings could also potentially foster environments leading to mood disorders, such as depression. Urban dwellers can be susceptible to hyperthermic state in a future warm climate and growing urban form. The urban population can thus be more prone to internal pathological conditions that harbor a risk for stroke, neurodegenerative diseases, and mood disorders. The impact on health and chronic illness due to temperature and climatic factors has been addressed in past studies. Here, we highlight that it is imperative to understand the effect of the heterogeneous urban environment on human health. This understanding requires enhancing the current urban morphological database and climate datasets because the inference made in most of the health studies uses data which are coarse resolution and representative of city but not neighborhoods and its variability. Hence, climatic adaptation (heat mitigation) activities such as an improved urban database covering the heterogenous urban environment would help assess the health impacts and incorporate proper mitigation methods.

In conclusion, (i) the impact of urban climate, air pollution and urbanization on the pathogenesis of neurodegenerative diseases and mood disorders is an area that needs further investigation; (ii) urban climate- health studies need to consider the heterogeneity in the urban environment and the impact it has on the UHI. More specifically, neurourban studies need to go beyond the use of airport-based representative climate data to a consideration of more spatially explicit, high-resolution environmental datasets for such health studies, especially as they pertain to the development of locally-relevant climate adaptive health solutions. Recent advances in the development of super-resolution (downscaled climate) datasets using computational tools such as convolution neural networks (CNNs) and other machine learning approaches, as well as the emergence of urban field labs that generate spatially explicit temperature and other environmental datasets across different city neighborhoods, will continue to become available. Future climate – health studies need to develop strategies to benefit from such urban climate datasets that can aid the creation of localized, effective public health solutions.

Abbreviations

AD	Alzheimer's Disease
CNN	Convolution Neural Network
DAMPs	Damage Associated Molecular Patterns
GLOBUS	Global Building Heights for Urban Studies
LTD	Long Term Depression
LTP	Long Term Potentiation
OR	Odds Ratio
PT Pore	Permeability Transition Pore
PD	Parkinson's Disease
ROS	Reactive Oxygen Species
sgPFC	Subgenual Prefrontal Cortex
UHI	Urban Heat Island
WRF	Weather Research and Forecast model
WUDAPT	World Urban Database and Access Portal Tools

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Authors' contributions
KT conceived the idea and contributed to the core content of the paper, including the impact on neuropathologies. KT also wrote the first draft and subsequently refined the manuscript. MT and DN provided input regarding urbanization and climate change, while KT synthesized the concepts into a cohesive idea. All the authors edited the final version. The author(s) read and approved the final manuscript.

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Availability of data and materials
No datasets were generated during the current study. The analysis of METAR datasets is presented from the previous work of one of the co-authors (MT) of this study. The graphics are generated using NCAR command language (NCL).

Declarations

Competing interests
The authors declare no competing financial or non-financial interests.

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