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Perceived causes, exposures and adjustments to seasonal heat in different residential areas in Ibadan, Nigeria

Olalekan John Taiwo · Hezekiah Daramola Olaniran · Tolulope Osayomi

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Abstract Local perception can be an important resource for assessing and managing climate-related extremes and identifying adjustment strategies unique to specific settings. The objectives of the study are two-fold. Firstly, it examined the perceived causes, exposures and adjustments to seasonal heat events using different residential density areas of Ibadan, Nigeria, as spatial units of analysis. Secondly, it investigated the relationship between heat exposure, built environment, socio-economic and cultural factors. Results show that intense heat from the sun, climate change and absence of rains, among others, was identified as perceived causes. Number of electricity hours, distance from water supply points and the number of neighborhood trees were listed as the three most important factors affecting heat exposure. In addition, there were considerable variations in the perceived causes ($F = 4.86$, $p < 0.05$), in exposures ($F = 3.61$, $p < 0.05$), and in adjustments to seasonal heat ($F = 8.75$, $p < 0.05$) across different residential density areas in Ibadan, Nigeria. The study demonstrates that local knowledge based on the perceptions, exposures and adjustments to seasonal heat waves has the potential in some cases to provide valid inputs into vulnerability and adaptation assessments.

Keywords Perception · Seasonal heat · Climate change · Nigeria

O. J. Taiwo · H. D. Olaniran · T. Osayomi (✉)
Department of Geography, University of Ibadan, Ibadan, Nigeria
e-mail: osayomi@yahoo.com

1 Introduction

Climate change has become a certainty in today's world posing challenges for food security, natural ecosystems, freshwater supply and human health. The Intergovernmental Panel on Climate Change (IPCC 2001) estimated that the global mean temperature will increase from 1.4 to 5.8 °C by 2100. This unprecedented increase in temperature is expected to have severe impacts on the global hydrological system, ecosystems, sea level rise, crop production, human psycho-social comfort and related processes.

Human exposure to excessively warm weather, especially in cities, is an increasingly important public health problem. In particular, temperature extremes that exceed physiological limits can cause widespread mortality, as evidenced by the 2003 heat wave in Europe, which resulted in more than 15,000 human fatalities in France alone (WHO 2003). Indeed, the potential health effects of climate change have been extensively reviewed (Haines and Patz 2004; Patz et al. 2005; McMichael et al. 2006; Ebi et al. 2006). And as climate change advances, the studies are likely to increase.

Climate change is therefore expected to perpetuate health disparities at local, regional and global scales, while people in poor countries will face greater health risks, with fewer resources and less resilience than those in wealthy nations (Adger 2008; Donohoe 2003). Developing countries, especially, are expected to suffer more negative impacts than the developed ones. At the local level, the poor living in congested and improperly planned areas are likely to experience the adverse effects more than the rich. Studies have shown that the urban poor are most vulnerable to extreme heat (Longstretch 1999; Adger 2008). Also, the effects of climate change on human health will no doubt vary by region, topography and capacity for response (Patz et al. 2005). Due recognition of this fact is important because planning for and managing the health impacts of climate change will need to draw on local data, and it will involve local and regional authorities and healthcare providers. This is a matter of increasing concern now that current climate models predict a dramatic increase in the frequency, intensity and duration of temperature extremes (Meehl and Tebaldi 2004), through the combined effects of a shift toward warmer, and more variable temperatures (Easterling et al. 2000; Schar et al. 2004).

Few studies have examined relationships between the microclimates of urban neighborhoods, population characteristics, socio-economic and cultural factors, thermal environments that regulate microclimates, and the resources people possess to cope with climatic conditions, coupled with issue of climate injustice (Harlan et al. 2006). However, in the studies, little is known about the relationship between changing urban climates and the various socio-economic and cultural adjustments often adopted to mitigate climate-related discomfort for different residential areas in cities of developing countries, like Nigeria. This study, thus, investigated the perceived causes, exposures and identified adjustment strategies against seasonal heat across different residential areas in Ibadan city, Nigeria. In addition, it examined the relationship between built environment, socio-economic and cultural factors and the identified adjustment strategies across different residential areas.

2 Data and methods

The study area, Ibadan city, is the capital of Oyo State. It is located in the southwestern part of Nigeria (Fig. 1), and it comprises five Local Government Areas (LGAs) (see Fig. 2). It is not only one of the oldest cities in Africa but the most populous black African city (Mabogunje 1962). Ibadan has varied residential density areas and therefore provides a platform for the examination of the household responses to heat and the various adjustment mechanisms that have been adopted by the residents to cope with the seasonal high temperature during the dry season, between

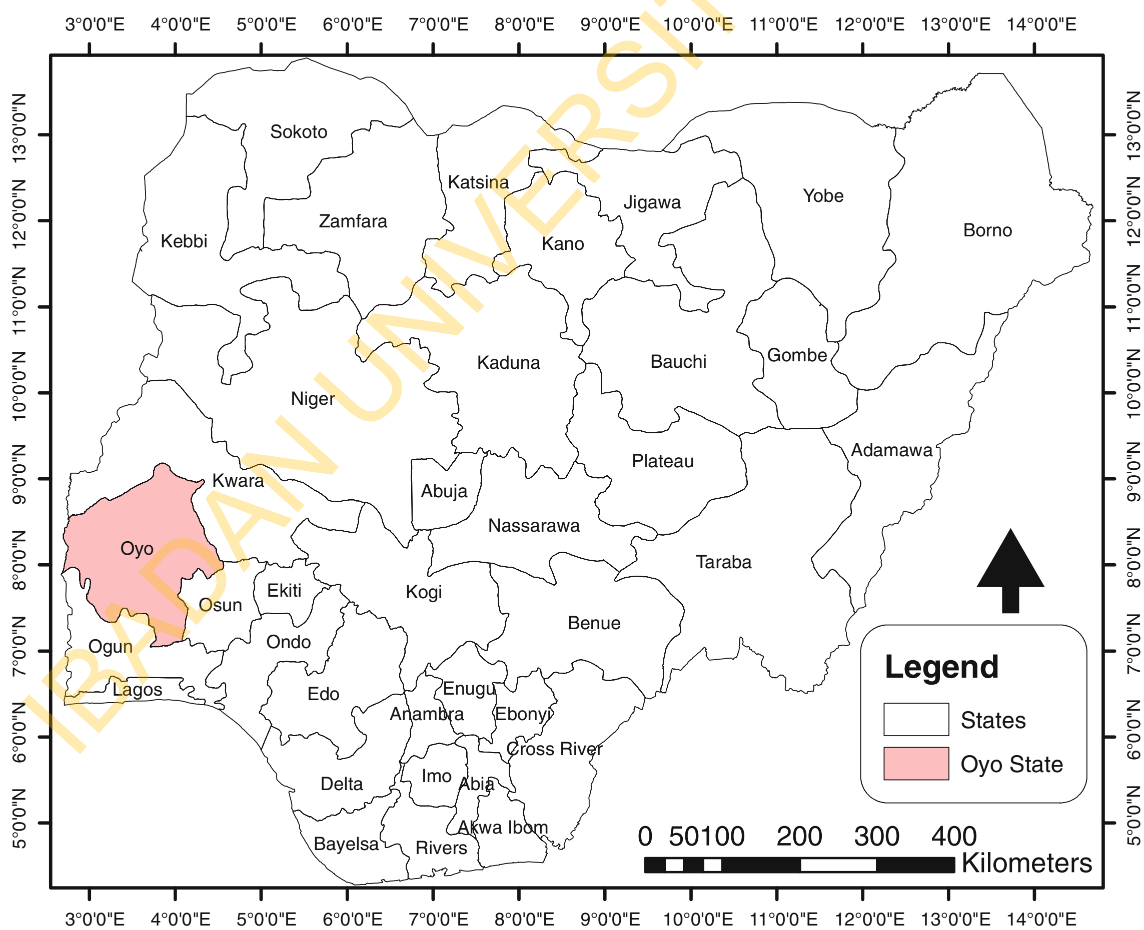

Fig. 1 Oyo State within the context of Nigeria

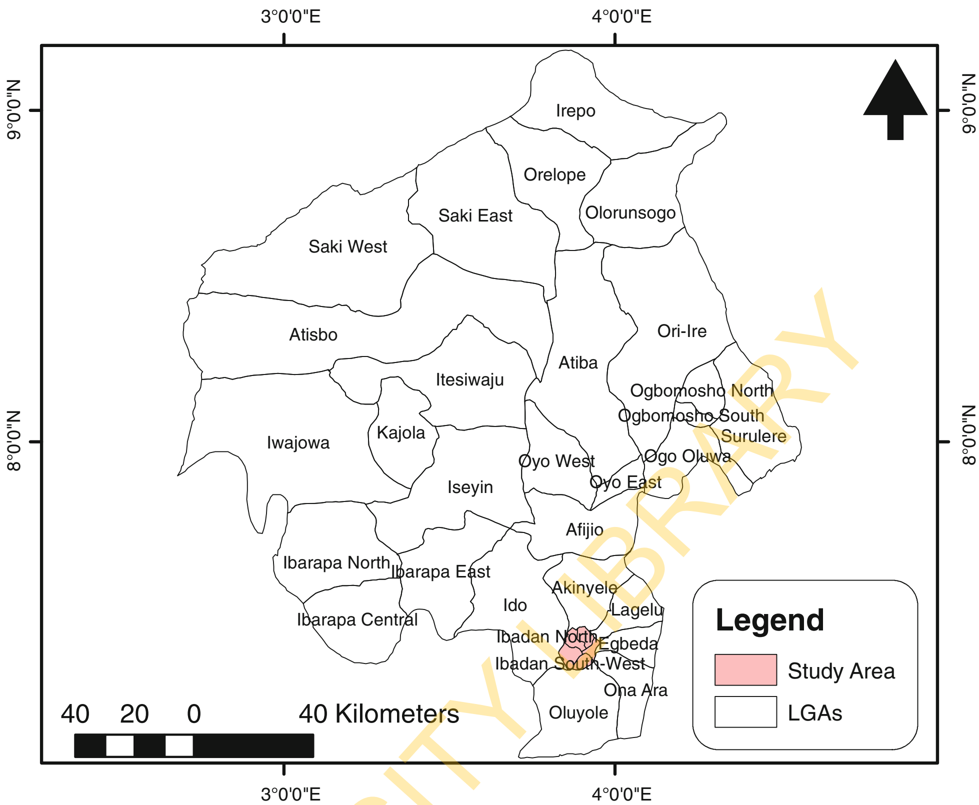

Fig. 2 The study area within the context of Oyo State

the months of October and April. The study was conducted in the dry season during which indoor and outdoor temperatures were greater compared to other seasons, so that the heat effects could be assessed.

The building density was used as a surrogate for population density which was not available at a better scale; hence, the study area was classified into three residential areas based on the extracted building footprints from a georeferenced high-resolution satellite image (Ikonos) covering the study area. The image had 0.6 m resolution and showed buildings, road networks and other physical features of the landscape. The image was georeferenced using sixteen randomly selected landmarks that were mostly road intersections. Building footprints were extracted through the process of heads up digitizing as polygons and stored in a Geographic Information System (GIS) geodatabase. The building frequency was calculated by overlaying the study area with 200 m^2 grids and number of buildings within each square grid assigned to their corresponding grid feature. Housing density per square grid was determined by dividing the area of each grid by the number of buildings it contained. The resultant value represented density of buildings within the 200 m^2 square grid. The choice of the 200 m^2 grid was based on the need to determine density at a smaller scale than what ordinarily obtained at the local government area levels. Other scales could however be employed to improve the resolution of this study. A thematic classification of the grid resulted in the pattern of residential density distribution within the delineated area.

Information on the perceived causes, exposures and adjustment strategies to the seasonal heat waves adopted by the residents was obtained using structured questionnaire. It covered questions on socio-economic characteristics of respondents, perceived causes of heat, factors that predisposed respondents to heat and the combinations of adjustment strategies employed to secure the needed comfort during the seasonal heat period. Since the housing density was mapped at 200 m^2 grid, it was easy to administer the questionnaire randomly using the same grid resolution. Hundred square grids each were randomly selected from the high-density, medium and low-density residential areas, respectively. In each of the grid, one house was randomly selected for the purpose of questionnaire administration. All these selected houses were located on ground, and the questionnaire was administered in these houses. Typically, the questionnaire was administered to household heads.

The mean aggregate distance separating houses within each sampled grid was obtained by measuring direct distance between two buildings and divided by the number of such measurements carried out within each grid. The result provides information on the distance separating houses from each other. In all, a total of three hundred respondents were sampled, with one hundred respondents drawn from each residential density type. Simple percentages and graphs were used in showing the perception of causes and exposure to heat, and the various adjustment mechanisms often adopted by the residents. Variations between residential density, socio-economic characteristics, perception, exposure and adjustment to heat were statistically determined using analysis of variance (ANOVA).

3 Results and discussions

3.1 Socio-economic characteristics of residents

Three indicators were used in assessing the socio-economic characteristics of residents in the three residential areas. These included income, education and building type. These indicators are believed to be of great importance in conceptualizing the perception and adjustment strategies to the seasonal cycles of heat. Furthermore, these indicators could be very important in segregating the area of study into different residential density areas. In the low-density area, the income cluster was between N51,000 and N400,000, while only about 1.67 % earned more than N401,000 monthly. In the medium income category, 17.34 % indicated they earned below N50,000 monthly, while 15.33 % earned between N51,000 and N400,000 monthly. Less than 1.0 % earned more than N401,000 monthly. In the high-density area, 23.0 % earned less than N50,000 monthly, while 10.33 % earned between N51,000 and N200,000 monthly (see Table 1). The analysis reveals the unequal income distribution in the different residential areas under consideration. The statistical analysis confirms that there was a significant difference in income distribution among the three residential densities ($F = 0.000$, $p < 0.005$).

Table 2 provides information on educational attainment among the sampled respondents. The percentage of respondents with tertiary education (18.33 %) was highest in the low-density areas, while it was least (5.33 %) in the high-density area. Conversely, the lowest education level was observed in the high-density areas, and this was followed by the medium density (2.67 %). The table shows that the highest educational qualifications were in low-density, and the lowest educational qualifications were in the high-density areas. However, from the table, it is evident that most of the sampled respondents were literate, if literacy is taken to mean basic primary education. The result of the analysis also confirmed that there was a significant difference in educational attainment in the three residential densities ($F = 0.000$, $p < 0.005$).

Different buildings based on their designs responded to heat in different ways (Jianguo et al. 2007; George and McGeehin 2008; Koppe and Jendritzky 2005). In Ibadan city, bungalow (12.67 %) and duplexes (8.33 %) dominated the low-density area while bungalows (11.00 %) and story buildings (8.67 %) were common in the medium-density area. Also, story buildings (11.00 %) and Brazilian building type (9.67 %) were common in the high-density residential areas (see Table 3). The data show that there were variations in the dominant building types in these residential areas. The result of the analysis confirms that there was a significant difference in housing types in the three residential densities ($F = 0.000$, $p < 0.005$).

3.2 Perceived causes of seasonal heat

Both physical and human factors were identified as the major causes of the seasonal heat often experienced in the city. A total of eight factors were identified as the major causes of heat in the city of Ibadan. A larger percentage of the respondents (23.67 %) indicated the sun had become too hot. The breakdown of this figure shows that 7.33 % of the respondents in the low density, 8.67 % in the medium density, and 7.67 % in the high density recognized that the heat from the sun had in the recent times been too intense (see Table 4). Thus, the perception of the solar intensity varied across the different residential areas. They responded that as from 9:00 a.m. till 9.00 p.m, it was hot indoors.

Table 1 Income distribution in the three residential areas

S/No	Income categories (Naira)	Low-density areas		Medium-density areas		High-density areas	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
1	Less than N20,000	0	0.00	11	3.67	31	10.33
2	20,000–50,000	0	0.00	41	13.67	38	12.67
3	51,000–100,000	23	7.67	19	6.33	18	6.00
4	100,000–200,000	52	17.33	15	5.00	13	4.33
5	201,000–400,000	20	6.67	12	4.00	0	0
6	401,000–800,000	5	1.67	2	0.66	0	0
7	Greater than 800,000	0	0.00	0	0.00	0	0
	Total	100	33.34	100	33.34	100	33.33

Source Survey data, 2009

Table 2 Educational status of respondents in the three residential areas

S/N	Educational categories	Low-density areas		Medium-density areas		High-density areas	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
1	No formal education	0	0.00	8	2.67	12	4.00
2	Quranic education	10	3.33	7	2.33	5	1.67
3	Primary school	11	3.67	22	7.33	29	9.67
4	Secondary school	24	8.00	44	14.67	38	12.67
5	Tertiary education	55	18.33	19	6.33	16	5.33
	Total	100	33.33	100	33.33	100	33.34

Source Survey data, 2009

Table 3 Building types in the three residential areas

S/N	Building categories	Low-density areas		Medium-density areas		High-density areas	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
1	Duplex	25	8.33	13	4.33	0	0.00
2	Bungalow	38	12.67	33	11.00	21	7.00
3	Brazilian building type	3	1.0	13	4.33	29	9.67
4	Block of flats	16	5.33	15	5.00	17	5.67
5	Story buildings	18	6.00	26	8.67	33	11.0
	Total	100	33.33	100	33.33	100	33.34

Source Survey data, 2009

The heat greatly affected their physiological comfort, and it exposed them to heat-related skin conditions like rashes, particularly where the houses lacked good ventilation and quality roofing materials. Generally, it was therefore agreed that nowadays the solar intensity had increased, compared to the past.

Table 5 also confirms that the dry season temperature in the city had been on the increase in the past few years. The respondents similarly indicated that the sunshine hours had also increased, in the recent times. The increased heat experience might have fostered a sense of increased sunshine hours on people's memory, nevertheless. The percentage of the respondents in the low-density residential area that indicated that the sunshine hours had increased was 5.33 %, while 6.67 % indicated same in the medium and 4.33 % in high-density residential area. Generally, 16.33 % indicated that the hours of sunshine had significantly increased.

The percentage of respondents that identified climate change as the major cause of the heat was 9.99 %. The breakdown of this outcome shows that the largest percentage for this response, that climate change was the major cause of the heat, was observed in the low density, and the least percentage was recorded in the high-density residential area. Absence of rainfall was identified by 23.00 % of the respondents as the cause of the heat. The breakdown of this figure for absence of rainfall shows that 7.6 % of the respondents indicated this factor in the

Table 4 Perceived causes of seasonal heat in the study area

Perceived causes of seasonal heat	Low-density areas		Medium-density areas		High-density areas		
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Total
The sun is too hot	15	5.00	26	8.67	23	7.67	21.33
Sunshine hours are increasing	12	4.00	20	6.67	13	4.33	15.00
Climate change	13	4.34	10	3.33	07	2.33	10.00
Absence of rainfall	18	6.00	23	7.67	28	9.33	23.00
Absence of cloud	09	3.00	04	1.33	06	2.00	06.33
Wind is still	10	3.33	07	2.33	12	4.00	09.67
Urbanization	14	4.66	02	0.67	05	1.67	07.00
Industrialization	09	3.00	08	2.67	06	2.00	07.67
Total	100	33.33	100	33.34	100	33.33	100.00

Source Survey data, 2009

Table 5 Minimum and maximum temperature (°C) pattern in Ibadan for 5 years

Years	Maximum temp °C	Minimum temp °C
2004	32.4	24.2
2005	30.5	25.5
2006	32.5	23.7
2007	32.4	24.1
2008	32.4	24.1

Source Forestry Research Institute of Nigeria, 2008

medium density and 9.33 % of the high-density area people identified this as the major cause of the extreme heat in their neighborhoods. Other factors for the increased heat identified include absence of cloud by 6.33 % of the respondents; no wind by 9.66 % of the respondents; urbanization by 4.67 and 6.35 % indicated industrialization.

3.3 Factors affecting heat exposure

Harlan et al. (2006) contended that human exposure to excessively warm weather, especially in cities, was an increasingly important public health problem. Demographic, housing, medical history and human adaptation factors, moreover, have been identified as important factors that affect human exposure to extreme weather conditions (Harlan et al. 2006; Basu and Samet 2002). In Africa, economic, housing and planning-related factors appear to importantly contribute to heat exposure. The heat exposure factors generally identified include hours of electricity supply, distance from water supply points, number of trees around the house, average monthly income, number of people with a minimum of primary school education, housing ventilation status, building density, aggregate mean distance separating buildings, daily maximum hours spent under the sun and private car ownership status.

Average electricity hours of 2, 4 and 6 were recorded for the high, medium and low-density residential areas. However, the epileptic nature of electricity made it difficult for some to adequately indicate the average number of electricity hours per day.

Distance from water supply points was also examined because of its effects in regulating body temperature. Its inclusion was based on the view that the closer residents were to water points, the less trouble would be experienced fetching bath water. And consequently, this reduced the impact of high temperature on body metabolism. The average distance (less than 1 meter) travelled to obtain water in the low-density residential area was the least, because almost all the houses visited had water supply and hence no need to travel to obtain water (see Table 6).

The role of trees in regulating temperature is well documented in the literature, particularly those dealing with urban forestry (Thompson 1980; Gornitz 1985; Nowak and Dwyer 2007). The average number of trees per house in the low-density residential area is 0.27 %, while that of the high-density residential area was 0.11 %. However, 9 % of the respondents in the low-density area had trees in their compounds, 4.3 % in the medium density also had in their compounds, and 2 % had trees in their compounds in the high-density area. Harlan et al. (2006) observed that high settlement density, sparse vegetation and having no open space in neighborhoods were significantly correlated with higher temperatures.

With respect to income, it is assumed that the higher the income is, the less the exposure to heat and the better individuals are able to cope with heat flux. This assumption is predicated on the premise that people with high income levels can afford to purchase gadgets to ensure maximum comfort during seasonal heat periods. In other words, it is expected that residents in high-density areas are less likely to cope with heat flux.

Similarly, exposure and adjustment to seasonal heat varied according to the educational attainments in the different residential density areas. People with higher levels of education were observed to have minimal exposure compared to those with low levels of education. This can be attributed to the fact that the people with higher levels of education will be more informed about causes of heat waves and on how they can adapt to the heat waves.

Private car ownership is also considered, as it contributes to the number of hours of exposure to the sun. The assumption here is that car owners spend less time under

Table 6 Factors affecting exposure to heat

Exposure factors	Low-density areas	Medium-density areas	High-density areas
Average hours of electricity supply	6	4	2
Average distance from water points (meters)	1	50	96
Average number of tree stands	27	13	6
Average income (in naira)	N60,000	N37,800	N10,200
Average number of people with private car	100	63	18
Average maximum hours spent in the sun daily	1	3	7
Average number of people with primary education	95	76	56
Average number of building with cross ventilation	100	88	44
Building density	2	4	8
Average distance between buildings	94	60	35

Source Survey data, 2009

the sun compared to non car owners who spent considerable time waiting for vehicles particularly during the afternoon. The challenge is more compounded at the close of schools when pupils and students take up almost all available commercial vehicles in the bid to return home early. In the survey, it was revealed that all the sampled respondents in the low-density residential areas had cars; 63 % indicated having cars in the medium-density area; and 18 % indicated so in the low-density residential areas. Car ownership therefore varied greatly among the sampled respondents in the three residential areas sampled. Coupled with the car ownership is the consideration for the number of hours spent daily in the sun. Thonneau et al. (1998) concluded that occupational heat exposure was a significant risk factor for male infertility, affecting sperm morphology and resulting in delayed conception. This occupational exposure to heat is a major factor in heat exposure particularly in low-density residential areas where the majority of respondents spend substantial time outside offices and homes.

The building-related indicators of heat exposure include ventilation status, building density and average distance separating buildings. All the buildings in the low-density residential area of the study had adequate ventilation in terms of ceiling materials and window condition; 88 % of buildings in the medium density also had adequate ventilation; and 44 % of buildings in the high density had it, in terms of ceiling materials and window condition. As regards building density, it was observed that the mean number of buildings (2) was least in the low-density area, while it was highest (8) in the high-density areas. The more the number of buildings is, the higher the local temperature would likely be, because of the high solar energy absorbance from all the impervious surfaces and due to the effect of the urban heat island. Housing interiors are often very hot in the evening because the heat absorbed by the walls is released, thereby increasing room temperature. In addition, buildings without ceilings are more probable to retain more heat than those with ceilings.

The average distance separating buildings in the low residential density area was found to be 94 meters, while it was 60 meters in the medium density and 35 meters in the low-density residential area (see Table 6). The closer the buildings are, the less effective air circulation will be and the more heat that will likely be experienced by the residents. The situation can be more challenging in locations dominated by high-rise buildings, which obstruct both horizontal and vertical air circulation. The high-density areas comprised mostly bungalow buildings and this might have made it possible for people to manage the heat, particularly in the afternoon and evening periods. The high-density residential areas had the least mean distance separating buildings compared to the low density where the mean distance was the highest.

3.4 Adjustment mechanisms

The various adjustment mechanisms adopted by residents in the inner city are often influenced by the socio-economic statuses of the individuals. Basu and Samet (2002) established that most common heat adaptation measures used included wearing less clothing, opening the windows, drinking more fluids, avoiding outdoors, using air conditioners, taking cold baths/showers, going to public places that have air conditioning, swimming and turning the fan on. Altogether, ten socio-cultural and five economic adjustment strategies to heat were identified by the residents, in the study areas of Ibadan city. The economic adjustments are those strategies that involve spending more money to obtain the needed comfort during the dry season. The economic adjustment therefore basically impacts on income and well-being. On the other hand, the socio-cultural adjustment relates to behavioral and attitudinal changes due to the change in weather.

Of all the identified socio-cultural adjustment, respondents for cold baths twice daily accounted for the largest percentage (53.3 %), and this was followed by the respondents for use of non-moisturizing cream (44.4 %). The percentage that indicated the use of sleeveless garments was 37.8 %. These were the three most often employed adjustment mechanisms in the inner city area. Three of the least used approaches to managing the heat included eating cold food indicated by 4.0 % of the respondents; sleeping on the floor instead of the bed by 5.0 %; and staying out late in restaurants and hotels to reduce heat effect by 8.0 %. Three most identified economic adjustment strategies in the study residential areas included increased budget for fueling generating set, indicated by 66.4 % of the respondents; the use of air conditioning in cars and houses, indicated by 43.8 %; and purchase of sleeveless and light wears, by 28.6 % of the respondents. The small percentage of respondents (7.3 %) that indicated overseas traveling might not be unconnected with the amount of money it involved (see Table 7).

The breakdown of the adjustments by the different residential types is contained in Table 8. In the low-density residential areas, the use of air conditioners, fan and sleeping without cover cloth are the three leading adjustment mechanisms often adopted by the residents. Respondents that depended on the use of air conditioners both at home and offices accounted for 9.33 %, while 7.33 % indicated the use of electric fan to mitigate excessive heat. However, people with low incomes who were vulnerable to health-related mortality might not have access to air conditioning (Basu and Samet 2002). 4.0 % of respondents slept without cover clothes and pajamas in the sampled population. Staying out late in the night and applying heat powder were the two least adopted

Table 7 Socio-cultural and economic adjustment to seasonal heat waves

S/N	Socio-cultural adjustment	Percent	Economic adjustment	Percent
1	Staying out late in restaurants and hotels to reduce heat impact	8	Increased budget for fueling generating set	66.4
2	Drinking cold water/beer	19	Purchase of sleeveless garments by women and knickers by men	28.6
3	Sleeping on the floor instead of the bed	5	Increased spending on purchase of ice block and cold water to mitigate the heat waves	15.4
4	Drinking more water	10	Repair and use air conditioners in the cars and homes to mitigate the impact of heat waves	43.8
5	Eating cold food	4	Traveling abroad	7.3
6	Rubbing heat powder on body	20		
7	Wearing sleeveless garments	37.8		
8	The use of non-moisturizing cream	44.4		
9	Sleeping outside and at balconies of houses	12.7		
10	Cold baths twice daily	53.3		

Source Survey data, 2009

Table 8 Adjustment strategies

S/No	Low-density areas	Frequency	Percent	Medium-density areas	Frequency	Percent	High-density areas	Frequency	Percent
1	Use of air conditioner	28	9.33	Use of air conditioner	23	7.67	Use of fan	27	9.00
2	Planted trees	6	2.00	Use of fan	18	6.00	Sitting under tree canopies	8	2.67
3	Use of fans	22	7.33	Opening of windows and doors to allow for cross ventilation	16	5.33	Sleeping outside the house till late in the night	15	5.00
4	Opening of windows	10	3.33	Staying out late	9	3.00	Staying out late at night	12	4.00
5	Bathing twice daily	8	2.67	Sleeping without cloth	12	4.00	Rubbing chalk (kaolin) on body	4	1.33
6	Bathing with cold water	10	3.33	Bathing with cold water	10	3.33	Bathing with cold water	7	2.33
7	Sleeping without cover cloth	12	4.00	Sitting outside the house far into the night	12	4.00	Bathing twice daily	11	3.67
8	Staying out late	3	1.00				Sleeping without cover cloth	6	2.00
	Rubbing of heat powder	1	0.33				Drinking more water to compensate for the lost water	10	3.33
Total	100			100			100		

Source Survey data, 2009

approaches to mitigating excessive heat. In the medium residential density area, the use of air conditioner as indicated by 7.67 % of the respondents, use of fan by 6.0 %, and opening of windows and doors by 5.33 % were the three most often used methods to reduce the impact of heat on the residents. In the high-density residential areas, the use of fan as indicated by 9.0 %, sleeping outside the house till late in the night by 5.0 %, and staying out in restaurants till late in the night by 4.0 % were the three most often adopted strategy to reduce the impact of heat on humans.

Generally, the rich and affluent typically live in the low-density areas while the relatively poor occupy in the high-density areas, and the middle-income people occupy the medium-density residential area. The interactions of different socio-economic, planning and cultural variables either consciously or unconsciously produce these different densities. A number of socio-economic and cultural variables will readily correlate with residential densities. This is because residential differentiation is an expression of many psycho-socio-cultural and economic parameters that work either individually or jointly to determine where individuals live within the city. Hence, the perception, exposure and adjustment options available to individuals are oftentimes location-dependent.

The statistical analysis of the variations in the perception of the causes of heat in the three residential areas shows that there was a significant variation ($F = 4.86$, $p < 0.05$), in the perception of the cause of the extreme heat across the three residential areas. It was further observed that there was a significant variation between the identified causes of heat and income ($F = 4.624$, $p < 0.05$); educational status ($F = 7.443$, $p < 0.05$) and building type ($F = 5.614$, $p < 0.05$). These three factors are therefore important in the explanation of the variation in the perception of the causes of seasonal heat waves, often experienced in these three residential areas.

Factors that predispose different residential areas to heat waves also varied. Indeed, there was a significant variation in the exposure level experienced in the different residential areas ($F = 3.61$, $p < 0.05$). This is expected in view of the diversities observed in their socio-economic (income and education) and building characteristics. However, there were other socio-economic variables such as occupation and distance from place of work, etc., that could still predispose the people to heat waves. The observed variation shows that residents in the different residential areas had different degrees of exposure to heat and any intervention aimed at mitigating the impact of heat waves should focus on different residential areas rather than just on higher administrative units. Regulating heat exposure will therefore require addressing the myriads socio-economic factors that predisposed the people to heat. This is particularly important where it is possible to identify the high-risk population such as the elderly and children.

The coping mechanisms adopted in different residential areas also varied significantly ($F = 8.75$, $p < 0.05$), and they were also significantly related to the three socio-economic variables adopted for explaining the observed variations in heat waves. This implies that income, education and building types were important in the choice of the various adjustment strategies often adopted by individuals in the three residential areas. Adjustment strategies adopted were residential density area-specific, and hence, people in the high-density areas tended to have a defined pattern of adjustment through a combination of options while people in the low density also had their own unique strategies to cope with heat during the dry season. In addition, income, education and housing types exerted considerable influence on the choice of adjustment strategy adopted by the people. It implies that people with both high income and education had a certain type of adjustment style, which was unique to them, while people at the other extreme on these three variables also had their unique adjustment style.

4 Conclusion and policy implications

In summary, the study identified the perceived causes, heat exposure factors and adjustment strategies to seasonal heat events in different residential density areas of Ibadan city, Nigeria. From the study, a number of conclusions can be drawn. First, there are several factors that are perceived to be causes of seasonal heat. Second, the study brought to the fore many perceived factors of heat exposure and local coping strategies like sleeping under trees in the afternoon, bathing twice and thrice daily, applying white clay (kaolin) to the body, staying out late in relaxation centers, as some of the adjustment mechanisms often employed in the study areas. Third, considerable variations in perceived causes, heat exposure and adjustment strategies were noticed across the three residential density areas.

Government at all levels should work together to address the challenge of irregular power (electricity) supply in Nigeria so as to give opportunity for urban residents to use household gadgets that can provide bodily comfort during extreme heat. Government attention should be directed to the following: regular monitoring and reporting of seasonal heat events both in the print and electronic media; provision and access to cool clean drinking water both at home and workplaces; and hospitals and clinics should be adequately equipped to manage heat-related stress and other conditions.

No doubt, the study has demonstrated that local knowledge derived from the perception, exposure and adjustments to the seasonal heat waves has the potential in some cases to provide valid inputs into vulnerability and adaptation assessments, and fill gaps where scientific data collection is sparse. The approach for incorporating local knowledge into national assessments and adaptation strategies will be extremely beneficial. It is advised that government particularly at the local level should design area-specific action plans, based on the knowledge derived at the local settings, to tackle the challenge of extreme heat events in urban areas.

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