AN ASSESSMENT OF OUTDOOR HEAT DISCOMFORT IN SOME CITIES OF NORTHWESTERN NIGERIA

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ABSTRACT

This study assessed the outdoor heat discomfort in some cities in Northwestern region of Nigeria. Data on temperature were analysed using the humidex equation in order to determine the intensity and intensity range of heat discomfort in cities that included Sokoto, Gusau, Katsina and Kano as well as the region between 1950 and 2015. This was with the aim to bring out the spatial and temporal differences. Results show that intensity of heat discomfort varied from one month to another as well as yearly. The most pronounced level of intensity was *dangerous* although in some cases very low intensity of heat discomfort were experienced. Infact, the *no discomfort* intensity also occurred prominently. This indicated fluctuations in the intensity and intensity ranges of heat discomfort in cities and the region as a whole. Also, certain months (April, May and June) were consistent in the occurrence of heat discomfort although with various intensities *from no discomfort to heat stroke probable*. These results were presented using pie charts, frequency tables and percentages. The findings in this study necessitated recommendations that include the provision of shelter belts and the need to engage in tree planting, afforestation as well as establishment of green areas in neighbourhoods within cities amongst others.

Key words: Heat, Discomfort, Monthly, Northwestern Nigeria, Outdoor.

INTRODUCTION

The climate of an area has several variables or elements. Some of these elements include rainfall, temperature, wind, humidity and insolation amongst others. These elements tend to act together to affect the environment, while the environment also in turn affect them (Alaci and Olatunde, 2017). For example, the temperature of an area is determined by the position of the overhead sun, the season and amount, intensity and duration of the solar radiation. Therefore, temperature as an element of climate and as a resource is vital. This is because it influences and to some extent determines the health, agriculture, rate of evapotranspiration, precipitation in an environment as well as the thermal comfort or discomfort of human beings. In fact, human health and his thermal comfort are influenced more by climatic elements (especially temperature) than by any other element of man's physical environment (Lenzuni, Freda and Del Guadio, 2008).

Heat/Thermal comfort can be defined as a feeling or state in which a person has no wish to increase or decrease insolation or to adjust his/her ambient thermal environment (Prek, 2006).

Heat/Thermal discomfort on the other hand is a situation where the environment including the ambient temperature along with relative humidity of the environment becomes harsh or unbearable to its residents (Olatunde, 2016). Human beings are not the same, they vary in their feeling of comfort/ discomfort due to different metabolic rate, the type of cloths used, work load and type, age, food and diet, emotions, cultural experiences and influences and their climatic areas (Omonijo and Matzarakis, 2011). As a result of these differences, women tend to prefer slightly higher temperature than men, while people that are from the tropics may be a little comfortable with higher ambient temperature and humidity than those from temperate areas. Also outdoor workers and elderly people prefer warmer temperature in contrast to younger people (Stewart and Oke, 2010; Jendritzky and Tinz, 2009; Jendritzky et al., 2009).

In recent decades, the issues of global warming and climate change have been affecting both natural and artificial systems in the environment. These systems in turn determine the heat stress or comfort levels of people. This situation has brought the issue of heat comfort or discomfort to prominence worldwide. Even before now, statistical methods have been used to analyse the comfort levels of people in different parts of Nigeria. Some of these include the use of the Evapotranspiration Index by Ladell (1949), Ayoade (1978), and Ogunsote and Prucnal-Ogunsete (2003), and Potential Evapotranspiration (PET) used in Ondo State (Omonijo and Matzarckis, 2011). This is because heat discomfort may results in diseases of different kinds such as skin rashes, meningitis and stroke among others (Nastos and Matzarakis, 2006). However, none or very little (see Hashidu, El-Tantawi, and Hassan,2017) seems to have been done in this regard in the Sudano-Sahelian Ecological zone especially in the North-Western part of Nigeria. The aim of this article therefore is to assess the degree of outdoor heat discomfort in some cities of North-Western Nigeria. The specific objective is the assessment of the monthly and yearly variations of outdoor heat discomfort in some cities of northwestern Nigeria.

THE STUDY AREA

The study cities (Sokoto, Gusau, Katsina, and Kano) (Figure 2) are the northernmost in the north western region of Nigeria. The region is located between Latitudes 9°N to 13° 28′N of the Equator and Longitudes 3° 28′ E to 10° 37′ E of the Prime Meridian. The area is about 216,065 km^2 in size. The population of the region as of 2006 was about 35,915,417 (National Population Commission (NPC), 2006). This has been projected to about 50,710,249 at the growth rate of 3.136 % in 2017. The region and cities experience the tropical continental climate with very long dry season, from October to April/May (8 to 9 months) and a short rainy season, June to September (3 to 4 months). In this region, temperature is relatively high throughout the year with the annual average varying from 28°C in Sokoto to about 25° C in Kaduna. The diurnal range of temperature of the area is about 12 ° C. Depending on the season: rainy/wet or dry/harmattan, the average duration of sunshine hours per day varies between 8 and 12.9. Also, relative humidity varies with the time of the day and season of the year. Average night values during dry season vary between 20 and 25% and daily values vary between 30 % at dawn to 10 % in the afternoon. During the rainy season, it raises to about 80% in some areas, for instance, Kaduna in the study region (Olatunde, 2013).

Like other parts of Nigeria, the two dominant airmasses that determines the season are Tropical Maritime (mT) that results in rainy season and Tropical Continental (cT) that result in dry season. These airmasses inevitably affects the temperature of the study region as well as the thermal comfortability or otherwise of people (Olatunde, 2013). The study cities and region are also located in the Sudano- Sahelian Ecological Zone of Nigeria. The total annual rainfall for the region is about 800 mm with a single peak around August (Olatunde, 2013).All these together with various human activities such as construction, agriculture, housing and socio cultural activities have individually and collectively determined the degree of outdoor heat discomfort associated with cities in the region.

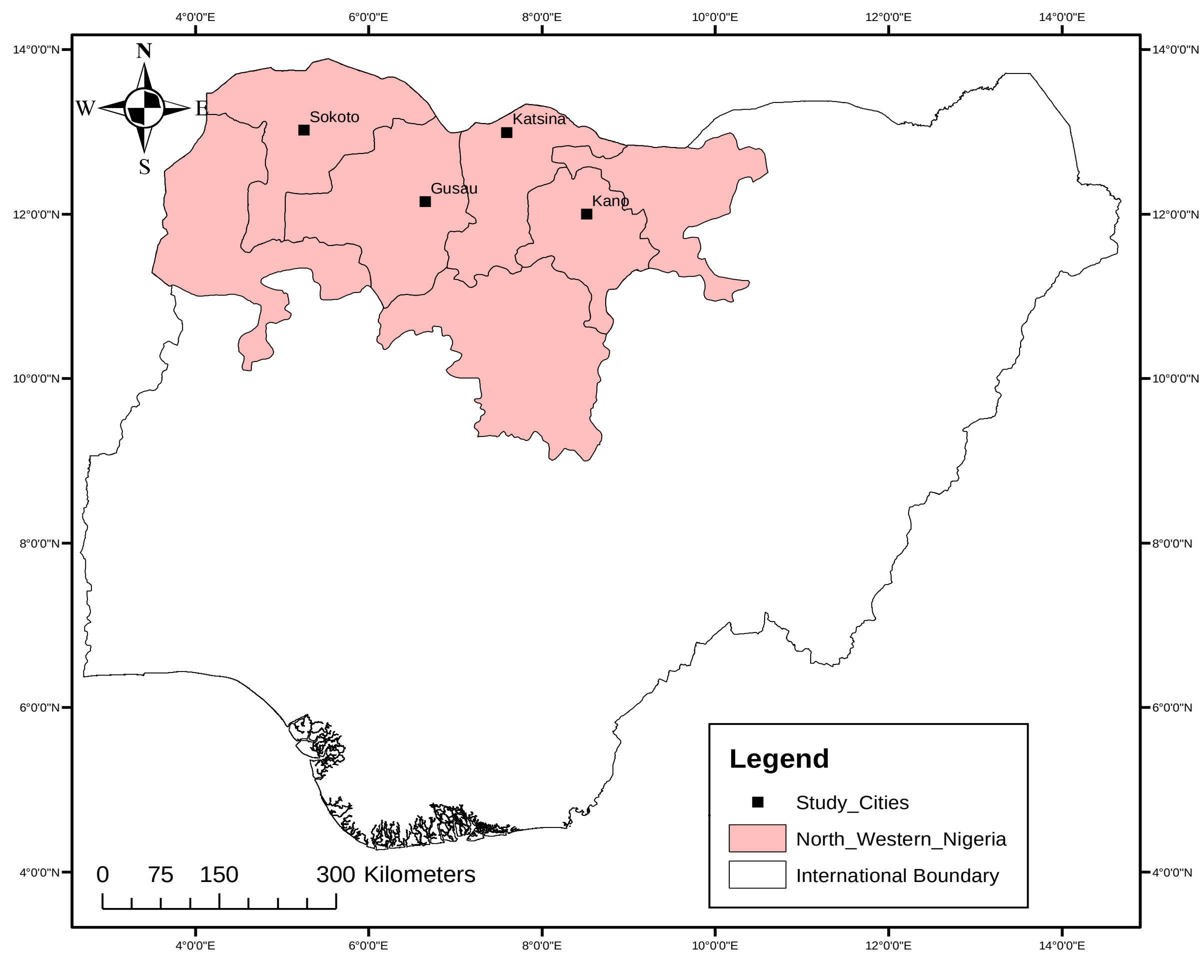

Figure 1: North-Western Region Showing Studied Cities
Source: Adapted from Olatunde, 2013

MATERIALS AND METHODS

Average monthly temperature data (January to December) of Sokoto, Gusau, Katsina, and Kano were sourced from The World Bank Group, Climate Change Knowledge Portal and other earlier researches (Eludoyi, 2011; Eludoyin et al., 2013; Abdussalam, 2015).The data were tested for normality using Kurtosis and Skewness, and were found to be normal. The number of years used for this study-66 years (1950-2015) was chosen to show the extent of heat discomfort over long period as well as to have more than one sub period, while the cities were those with long and continuous unbroken record of temperature. The data were used to determine the extent of heat discomfort in the cities mentioned above. This was done with the aid of the Humidex calculator. This index is based on the work of Masterton and Richardson (1979). The Humidex takes into consideration, temperature and vapour pressure and not other variables such as cloud cover, wind speed and so on. Its usage is appropriate for the region of study because data on these other variables are difficult to come by. The formular for the Humidex statistic is:

$H = T + (0.5555 \times (e - 10))$..(1)

Where;

e = Vapour pressure (mb) and is calculated as;

$e = (6.112 \times 10^{\wedge} (7.5 \times T / (237.7 + T)) \times H / 100)$,...(2)

H = Humidex

T = Temperature (^{0} C)

Table 1: Assessment Scale of Humidex Degree of Comfort

Humidex (°C)	Degree of Comfort
20–29	No discomfort
30–39	Noticeable discomfort
40–45	Intense discomfort
46 – 53	Dangerous discomfort
Above 54	Heat stroke probable

Source: Olatunde, 2016

Apart from these degrees of comfort/discomfort, the intensity of discomfort was also ranged for instance, from *No discomfort* to *noticeable discomfort*, *No discomfort* to *intense discomfort* and *Notice discomfort* to *heat stroke probable* and so on. This was used to find out the extent of outdoor heat discomfort over a range.

RESULTS AND DISCUSSION

The data were analysed in order to show the intensity and intensity range of outdoor thermal discomfort in each of the studied cities so as to bring out similarities and differences in the spatial and temporal occurrence of heat discomfort in the cities and the region as a whole.

Intensity of Heat/Thermal Discomfort as either Minimum or Maximum Experienced During Entire Study Period

In Sokoto, when the intensity levels were treated as individual minimum or maximum occurrence of thermal discomfort the results are as shown in Figure 2. *Noticeable* discomfort had the highest occurrence of 29% followed by *dangerous* at 25%. *No discomfort* 23%, and the highest level of thermal discomfort; *heat stroke probable* had 20%. The lowest at 1.5% was for *intense.* This shows that all levels of thermal discomfort were experienced and they all accounted for 77% of thermal discomfort, while *no discomfort* was only 23% during the studied period. However, in Gusau, the second city studied and as shown in Figure 3, the various intensities of thermal discomfort were experienced during the studied period, with *dangerous* being the highest at 38.6%, while *intense* was the lowest at 4.6%.

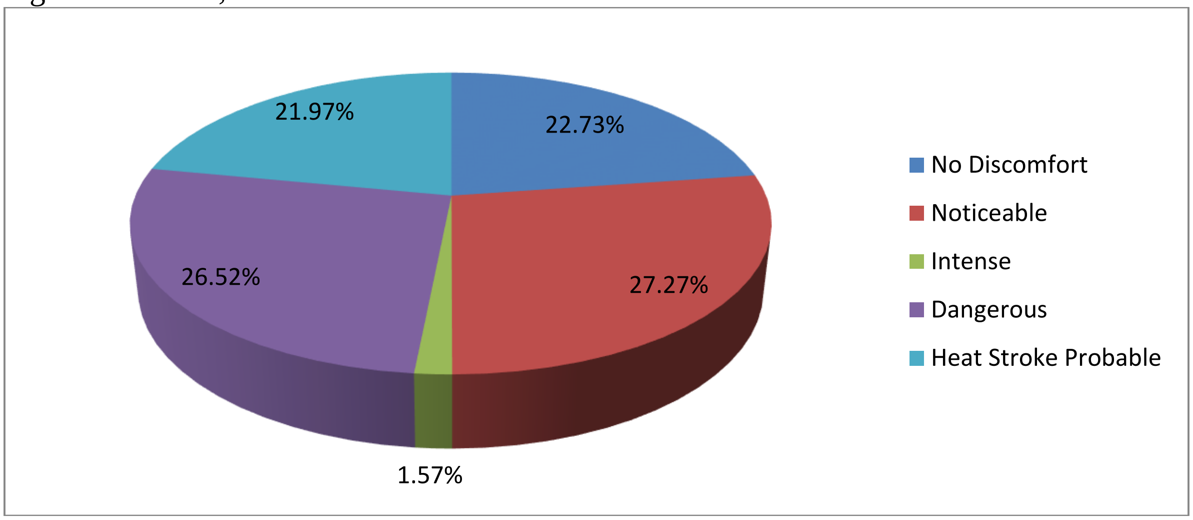

Figure 2: Intensity of Thermal Discomfort as either Minimum or Maximum during the Entire Period Studied (Sokoto)
Source**:** Authors' Analysis, 2018

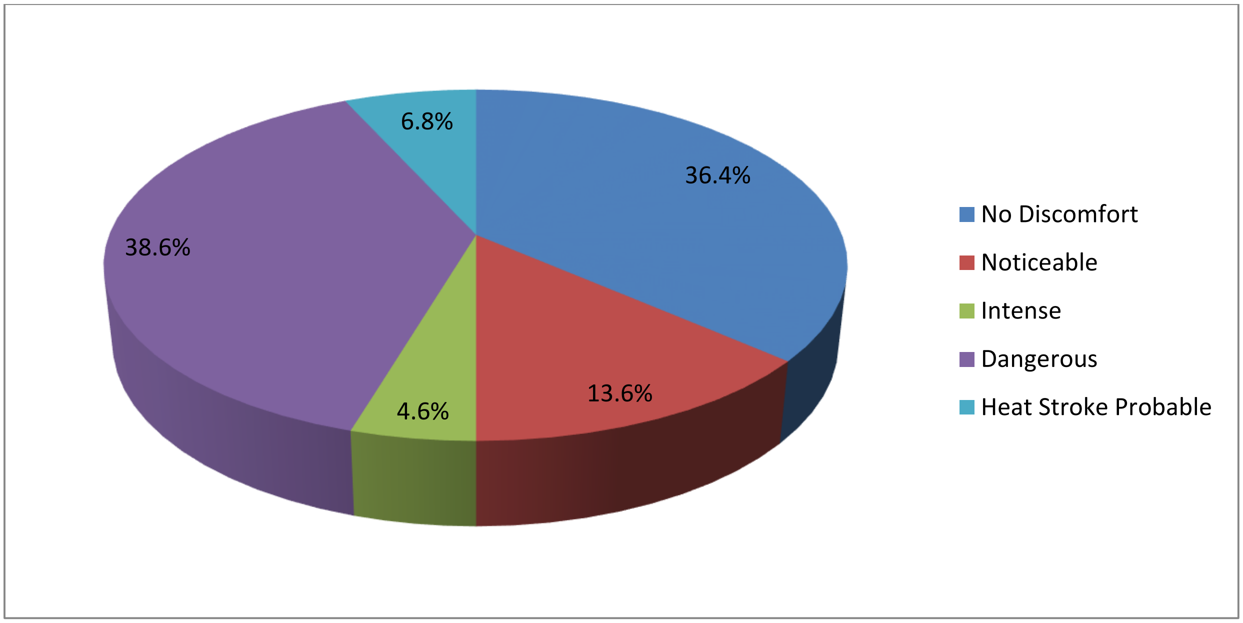

Figure 3: Intensity of Thermal Discomfort at either Minimum or Maximum Experienced during the Entire Studied Period (Gusau)
Source**:** Authors' Analysis, 2018

For Katsina, results indicated that the *no discomfort* intensity of thermal discomfort was experienced 63 times (47.73%). All other intensities of thermal discomfort were experienced in Katsina with various frequencies of occurrence. *Dangerous* was the most frequent (31%) while *heat stroke probable* being the highest level had a frequency of 8 (6%) as can be seen in Figure 4. Results indicated that a high percentage of *no discomfort* was experienced (44.7%) during the studied period in Kano. The others amounted to 55.3%, with *heat stroke probable* and especially *dangerous* constituting a major part of this percentage (Figure 5).

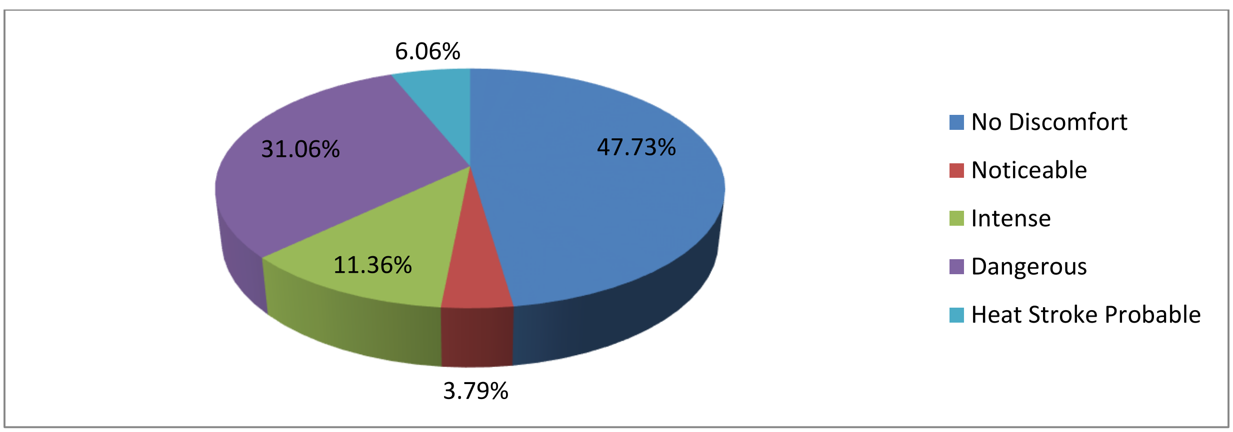

Figure 4: Intensities of Thermal Discomfort as either Minimum or Maximum Experienced during the Entire Studied Period (Katsina)
Source**:** Authors' Analysis, 2018

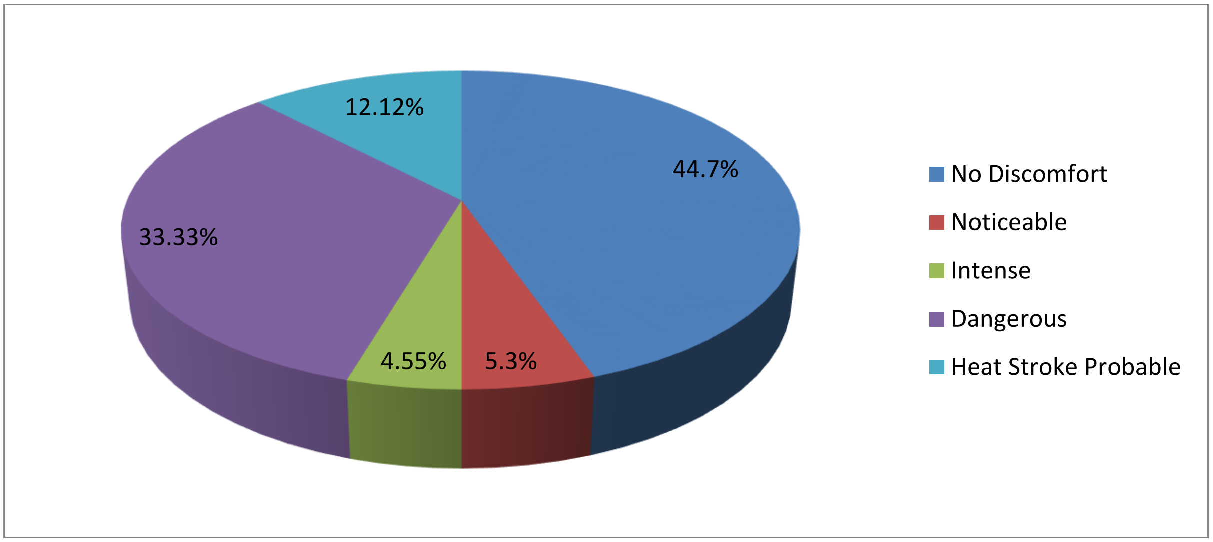

Figure 5: **Intensity of Thermal Discomfort as either Minimum or Maximum Experienced during the Entire Studied Period (Kano)**
Source**:** Author's Analysis, 2018

Monthly Occurrences of the Intensity Ranges of Thermal Discomfort during the Entire Studied Period

For Sokoto city during the entire studied years, the degree of discomfort ranged between *no discomfort* to *intense* twice (2) in April, once in May and September respectively. The intensity of heat discomfort reached *dangerous* five times (5) in the month of April, Fifteen (15) times in May, Nine (9) times in June and once each in July and September. It also ranged between *noticeable* to *dangerous* and *heat stroke probable*. Within this range, it got to dangerous in the month of April 3 times, May 16 times, June 9 times and once each in July and March. It reach the level of *heat stroke probable* once in March, twice (2) in April, thirteen (13) times in May, five (5) times in June and once in September. These results indicated May as the month when all levels of heat discomfort prevailed. It was followed by the months of June and April.

This research however showed that five intensity ranges of thermal discomfort were experienced in Gusau during the entire studied period. These include *no discomforts* to *intense*, the intense level being experienced mostly in April (3 times), May (5 times) and June (3 times). In the highest range, *noticeable to heat stroke probable; heat stroke probable* occurred in three May months, two June months, one April month, and one February month. All other ranges of intensities are as shown in Table 2. These results indicated that all the highest levels of the intensity ranges mostly occurred in the months of April and May and to a lesser extent in June. It also further revealed that the *dangerous* level of intensity occurred most during the studied period.

Table 2: Monthly Occurrence of Intensity Ranges of Thermal Discomfort during the Entire Studied Period

	Frequency of Occurrences											
Intensity Ranges	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
No Discomfort to Intense				3	5	3						
No Discomfort to Dangerous			1	14	32	3				3		
No Discomfort to Heat Stroke Probable			1	3	3		1					
Noticeable to Dangerous				8	15	1				1		
Noticeable to Heat Stroke Probable		1		1	3	2						

Source: Authors' Analysis, 2018

Results for Katsina indicated that six ranges of intensity were experienced during the entire studied period. When thermal discomfort ranged between *no discomforts* to *intense*, it occurred mostly in the months of May and June, while when it ranged between *no discomforts to dangerous* it was also May and June. When thermal discomfort ranged between *no discomfort and heat stroke probable*, it occurred in the months of May and June. Other intensities ranges months of occurrences are as shown in Table 3. It is clear from the result that all the six intensity ranges occurred most in the months of May and June and to a lesser extent April. For Kano city, results as shown in Table 4 revealed that all the six intensity ranges occurred in the months of May and June and to a certain extent in the months of April, July and September. The *dangerous* intensity level was the most experienced in Kano during the months of the studied years.

Table 3: Monthly Occurrences of Intensity Ranges of Thermal Discomfort during the Entire Studied Period

Intensity Ranges	Frequency of Occurrences											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
No Discomfort to Intense					12	08	01		03			02
No Discomfort to Noticeable						01						
No Discomfort to Dangerous.				02	24	15	04		05	02	01	
Noticeable to Heat Stroke Probable				02	04	03			01	01		
Noticeable to Intense				02		01			01			
Noticeable to dangerous					01							

Source: Authors' Analysis, 2018

Table 4: Monthly Occurrences of Intensity Ranges Thermal Discomfort during the Entire Studied Period

Intensity			Frequency of Occurrences									
Intensity Ranges	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
No Discomfort to Intense					04	01		01	01	01		
No Discomfort to Dangerous				18	34	25	02		03	04		
No Discomfort to Heat Stroke Probable				01	11	04	01		01	02		
Noticeable to Dangerous				01	02	04			01	01		
Noticeable to Intense				01	01		01		01			
Noticeable to Heat Stroke Probable					01	01	01					

Source: Author's Analysis, 2018

Yearly Occurrences of Intensity Ranges of Thermal Discomfort during the Entire Studied Period

On year to year basis in Sokoto, the level of heat discomfort ranged between n*o discomfort* to *Intense*, *dangerous* and *heat stroke probable*. Results as shown in Figure 6 indicated that the intensity of thermal discomfort did not exceed *intense* only in two years of the entire studied years. This is about 3.03% of the studied years. The intensity level got to *dangerous* sixteen (16) times (24.3%) and *heat stroke probable*, twelve (12) times (18.2%). Results further indicated that intensity of the thermal discomfort got to *dangerous* nineteen (19) times (28.8%) and to *heat stroke probable* Seventeen (17) times (25.5%), when the degree of discomfort ranged between *noticeable to dangerous* and *heat stroke probable*. These percentages that accrued *to dangerous and heat stroke probable* intensities may indicate high level of thermal discomfort during the studied years in Sokoto.

In Gusau, as shown in Figure 7, the ranges of discomfort that occurred most on yearly basis during the studied periods were *no discomfort* to *dangerous* at 53% and *noticeable to dangerous* at 22%. This proved the high level of heat discomfort in Gusau, although the intensity got to the highest level of *heat stroke probable* (6 %), its occurrence and frequency was not as much as *dangerous* (75 %) during the studied period.

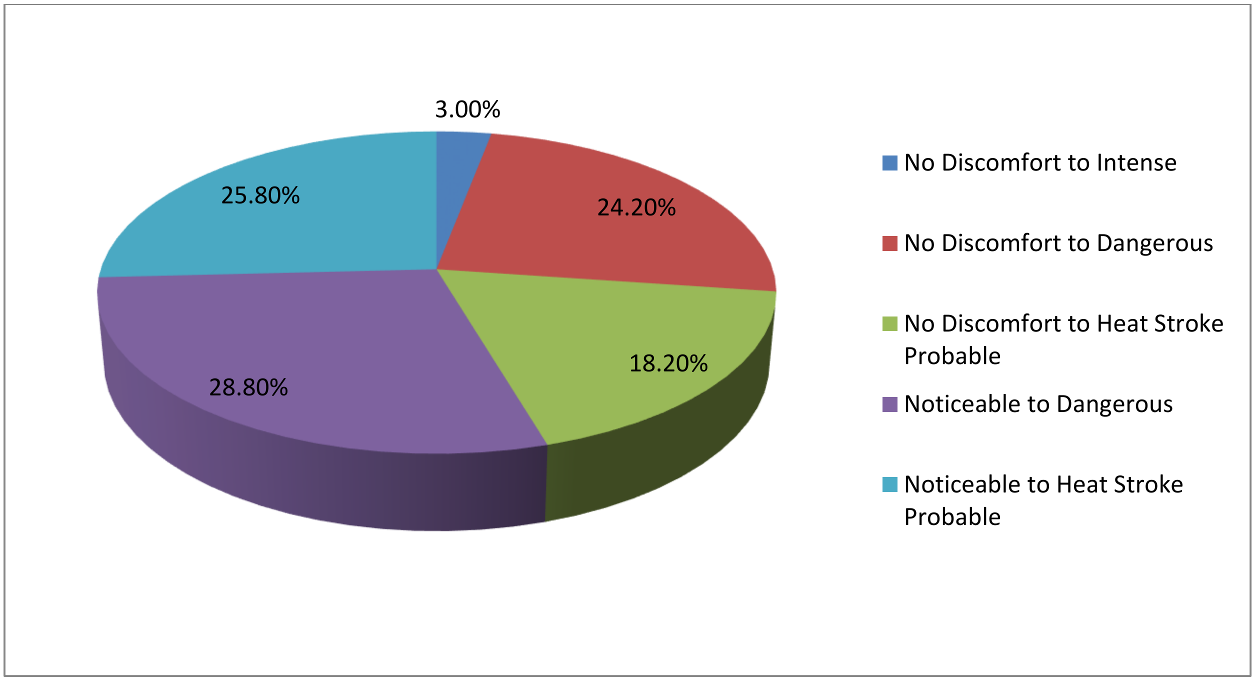

Figure 6: Yearly Occurrences of Intensity Ranges of Thermal Discomfort during the Entire Studied Period (Sokoto)
Source: Authors' Analysis, 2018

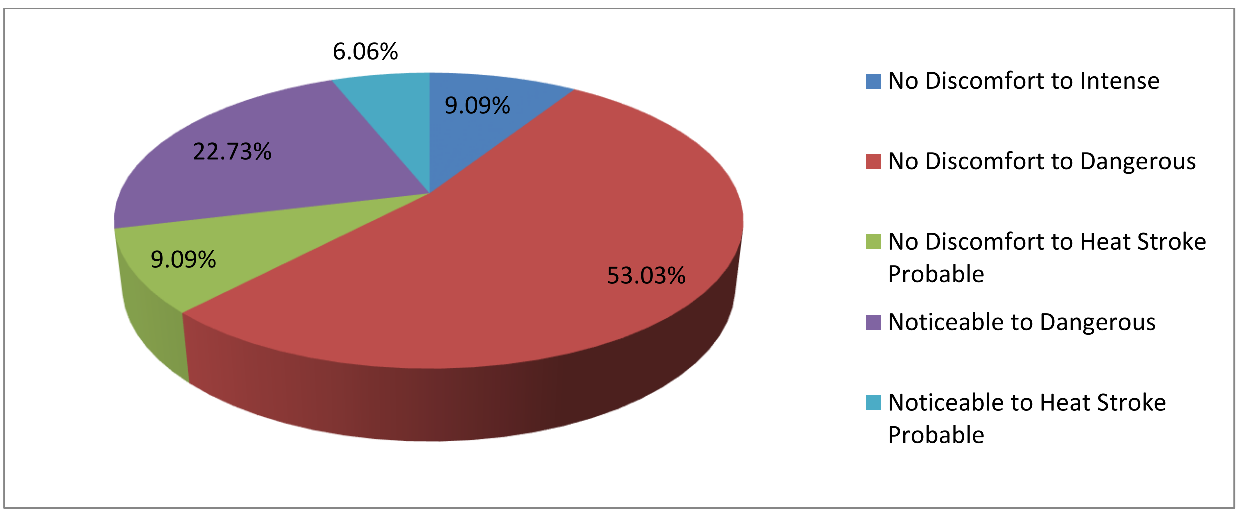

Figure 7: Yearly Occurrences of Intensity Ranges of Thermal Discomfort during the Entire Studied Period (Gusau)
Source: Authors' Analysis, 2018

The most dominant intensity range of thermal discomfort during the sixty-six years of study in Katsina was *no discomfort* to *dangerous* (Figure 8). This indicated that thermal discomfort got to the second most intense level (*dangerous*) severally in Katsina with the possible accompanying inconveniences and diseases. Other intensity ranges are as shown in Figure 8. In Kano city, results revealed the intensity range of *no discomfort to dangerous* as being the dominant. The other intensity ranges are as shown in Figure 9.

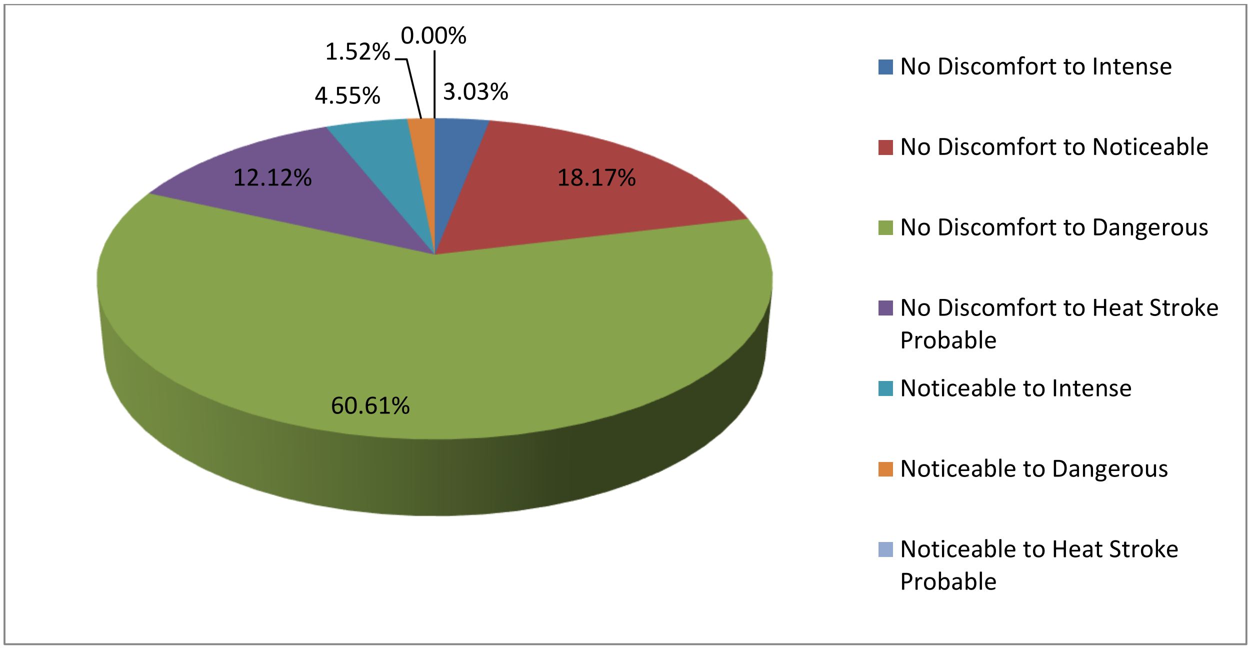

Figure 8: Yearly Occurrences of Intensity Ranges of Thermal Discomfort during the Entire Studied Period (Katsina)
Source: Authors' Analysis, 2018

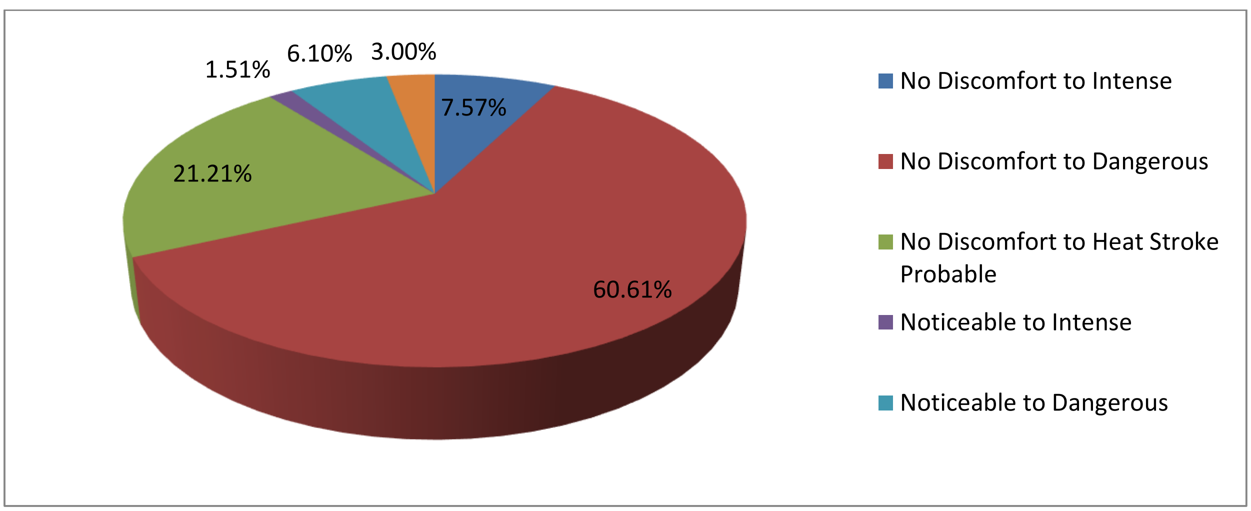

Figure 9: **Yearly Occurrence of Intensity Ranges of Thermal Discomfort during the Entire Studied Period (Kano)**
Source: Authors Analysis, 2018

In general, the degree of thermal discomfort in the cities as well as the north-west region of Nigeria as a whole was not static and varied throughout the studied period. Its intensity and range of intensity fluctuated from one extreme end to another. It fluctuated from *no discomfort* usually in the rainy months when the effects of rains and winds (mT) prevail and help to reduce the heat to *dangerous* and sometimes *heat strokes probable* especially in the months of change from the dry season to rainy season in April, May, and June and to a lesser extent from rainy to dry season in September and October. This may be attributed to the withdrawal of the cold Tropical Continental (cT) air mass as well as the intense convective activities associated with the onset of the rainy period. This situation agrees with the work Olatunde (2016) carried out in Lokoja which showed these months to be of high thermal discomfort.

On the other hand, this study indicated the occurrence of extreme thermal discomfort (*heat stroke probable*) which contradicts the work of Olatunde (2016) that indicated the absence of extreme thermal discomfort. This may be attributed to the latitudinal location of the studied cities and region. This position is backed up by the fact that Sokoto can said to have experienced more of the extreme heat discomfort (heat stroke probable) than other stations as shown by this research. On the other hand, it also experienced the least thermal discomfort(*noticeable and intense*) apart as well as *no discomfort, this might be attributed to the presence or intervention of other factors (apart from temperature) for instance, the low level of socio-economic activities as compared to Kano and Kaduna in the region.* The low percentages of occurrence of *heat stroke probable in cities like Katsina and Gusau might be attributed to low anthropogenic activities (for instance, presence of few industries) that might have resulted in urban heat island and high level of thermal discomfort.*

Heat discomfort intensity ranges were experienced from the lowest to the highest in the cities used. This further confirmed the fluctuations in intensity of heat discomfort in those cities. The increase in level of thermal discomfort in the months of April and May may be attributed to increase in convective activities while in September and October to the change in season. Results also indicated that the fluctuation in thermal discomfort level occurred in all the cities studied as well as from one year to another. The most pronounce level of intensity was *dangerous* although in some cases very low intensity of thermal discomfort were experienced as earlier mentioned. Infact, the *no discomfort* intensity also occurred prominently.

CONCLUSION

As a result of the combination of several factors such as latitudinal locations, vegetation type, topography, soils, and increase in socio-economic activities in the study region, it seems inevitable that the intensity of heat discomfort is bound to continue to fluctuate from one extreme end to another within the year in the study area. This situation means people in cities and towns in the region may have adapted to this rhythm. However, because of the current change in climate that may likely exacerbate the low amount of rain and scanty vegetation in the region that may worsen the already high heat discomfort in the study region as shown in the presence of dangerous and heat stroke probable intensities and the high intensity ranges, it becomes important for the people to be aware and be updated of the several measures that can be taken to mitigate or reduce the effects of heat discomfort. Some of these measures include but not limited to;

i. Boreholes and Pipe borne water should be provided to ameliorate the effects of thermal discomfort.
ii. Also, since this research revealed the *dangerous* level of intensity as the most experienced during the studied period. This tend to suggest the need for people to take appropriate measures that can reduce or ameliorate this high level of thermal discomfort, for instance, several baths in a day especially in the months of April and May (Olatunde and Ukoje, 2016) as well as drinking sufficient water.
iii. Tree plantings, Shelter belts and afforestation programmes should be carried out while green areas should be provided in neighbourhoods without them in order to modify the thermally stressful environment.
iv. In the months of April, May, June and to lesser extent in September and October, residents of cities in the region should avoid places without shades due to the high heat discomfort likely to be experienced.

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