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PUBLIC HEALTH IMPACTS OF HEAT WAVES: A REVIEW

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ABSTRACT

Background: The average rate of global temperature doubled from 0.07°C (0.13°F) to 0.17°C (0.31°F) per decade since 1970, which has contributed to the increased frequency and intensity of heat waves. Heat waves has gained more international concern and interest as a growing issue due to its various impacts. Of particular interest is the public health impacts involving morbidity, mortality, and burden of diseases related to heat waves.

Materials and Methods: Articles were chosen by using a systematic search via three electronic database, namely PubMed, Scopus, and ScienceDirect coupled with a combination of keywords namely “climate change” OR “global warming” OR “heat waves” OR “extreme heat” OR “temperature rise” AND “public health” OR “population health” OR “community health”. Other inclusion criteria included full accessible, original studies in English language, and published in a peer-reviewed journals from 1 January 2010 to 30 September 2017.

Result and Discussion: A total of seventeen heat related articles were eligible with six articles each on morbidity and mortality respectively while remaining five additional articles discussed were mainly on the burden of diseases related to heat waves. It was found that heat waves were associated with increased morbidity related hospitalisation and mortality due to exacerbation of existing medical conditions. However, as heat wave related mortality very much depended on the event location, timing and past experiences, morbidity was suggested as a more sensitive index in assessing the population health impacts. Interestingly, despite the hospitalisation due to heat wave related illness being relatively short with lower total charges, there was still high disparity and greater burden of cost especially among the marginalised group, with mean cost exceeding over USD1000 per hospitalization. This subsequently led to productivity loss as calculated by the disability-adjusted life years (DALY), which was 1.82 per 1000 population due to heat waves.

Conclusion: A public health concern was highlighted in relation to heat wave incidences. It remains crucial to identify the public health impacts of heat waves in order to find more comprehensive public health actions in planning and preparedness for future events.

Keywords: Heat waves, climate change, temperature rise, public/community health

1.0 Introduction

Heat waves generally refer to a period of unusually hot weather above the normal daily maximum temperature for at least two or three days (Stefanon, D'Andrea, & Drobinski, 2012). However, there is no universally agreeable definition for heat waves. During period of heat waves, both daytime and nocturnal temperatures, as well as humidity could reach high values beyond their long-term mean (NOAA, 2016). Heat waves are relative to local climate, therefore the same meteorological data could mean heat waves in a location but not for another. The intensity of heat waves may also differ substantially across regions.

In Malaysia, heat waves are defined as daily maximum temperature of 37°C for three consecutive days (Malaysian Meteorological Department, 2017). Malaysian Meteorology Department has established four levels in monitoring heat waves. Level 0 refers to temperature of less than 35°C, which is defined as safe temperature. Level 1 refers to temperature from 35 to 37°C for three consecutive days, whereby caution is warranted. Level 2 refers to temperature of more than 37°C for three consecutive days, whereby a heat wave period is defined. Lastly, level 3 refers to temperature of more than 40°C for three consecutive days, whereby an emergency will be declared under the circumstances (Malaysian Meteorological Department, 2017). For the level 2 and 3, public should follow the advice by relevant authorities and the weather update by Malaysian Meteorology Department.

Heat waves are growing issue as the frequency and intensity continue to increase with the global climate change (Watts et al., 2017). Since 1880, the global temperature increased at an average rate of 0.07°C (0.13°F) per decade and after 1970 it has doubled the rate to 0.17°C (0.31°F) per decade (NOAA, 2016). The magnitude and apparent temperature peak of heat waves have been strongly intensified by humidity, as observed in Chicago in 1995 and China in 2003 (Russo, Sillmann, & Sterl, 2017). During the major summer heat waves in central and western Europe in 2003, in Russia in 2010, it was postulated that the humidity, radiation, low winds, and air pollution potentially contributed to the additional deaths by tens of thousands (Barriopedro, Fischer, Luterbacher, Trigo, & Garcia-Herrera, 2011).

The concept of human survivability threshold based on wet-bulb temperature (TW) of 35°C was illustrated by Sherwood & Huber (2010). Wet-bulb temperature is measured by covering a standard thermometer bulb with a wetted cloth and fully ventilating it to allow evaporation until saturation. It measures the temperature (or dry-bulb temperature) and humidity. Wet-bulb temperature is always less than or equal to dry-bulb temperature. High values of wet-bulb temperature indicate hot and humid conditions. The metabolic heat generated by human body and absorbed solar heat must be lost from combination of heat conduction, evaporative cooling, and net infrared radiative cooling. However, the net conductive and evaporative cooling can only occur if human body is warmer than the environmental wet-bulb temperature. When wet-bulb temperature exceeds human body temperature, the law of thermodynamics does not allow heat lost to environment, irrespective of how wet or well-ventilated (Im, Pal, & Eltahir, 2017). Normal human body temperature is maintained within a very narrow limit of ±1°C, thus failure of thermoregulation can immediate impair physiological functions (Epstein & Moran, 2006). Sherwood & Huber (2010) concluded that wet-bulb temperature of 35°C or more for even a few hours will result in death.

Historically, the highest wet-bulb temperature rarely exceeded 31°C according to the global historical reanalysis for modern record from 1979 to 2010 (Dee et al., 2011). However, wet-bulb temperatures that exceeded 28°C were observed in three extensive regions, namely in southwest Asia around the Persian or Arabian Gulf and Red Sea, South Asia in the Indus and Ganges river valleys, and eastern China (Im et al., 2017).

General impacts of heat waves involve human health, socio-economic and agriculture. The impacts of heat waves were even more in low-and middle-income countries and among vulnerable populations (Watts et al., 2017). During heat waves in Europe in 2003, a preliminary analysis estimated that it caused more than 70,000 additional deaths in Europe (Robine et al., 2008). There were about 125 million additional vulnerable adults exposed to heatwaves between 2000 and 2016 (Watts et al., 2017). The heat stress in human body is more susceptible in individuals with poor thermoregulation especially among the sick and the elderly. On the other hand, heat waves also lead to socio-economic disruption. The economic loss resulting from heatwaves are enormous with evidences showed the increasing ambient temperature has resulted a 5.3% reduction in outdoor labour productivity globally. Each 1°C increase in minimum temperature during growing-season would result in a 10% decrease in rice grain yield (Peng et al., 2014). In addition, despite the fact that heat waves has incurred on healthcare costs with the burden of diseases as part of relevant socioeconomic impacts of public health, studies related to these affliction has been limited. Therefore the issue has been underestimated as the deep rooted factor in influencing a nation’s progress.

The purpose of this study was to conduct a systematic review of the literature concerning the impact of heat waves on public health, which will be discussed in terms of morbidity, mortality, and burden of diseases related to heat waves.

2.0 Materials and Methods

A systematic search of the literature was conducted by three electronic database, namely PubMed, Scopus, and ScienceDirect in September 2017. The above databases were searched using the following search criteria and a combination of keywords and search terms. The first group of keywords consisted of “climate change” OR “global warming” OR “heat waves” OR “extreme heat” OR “temperature rise”. The second group of keywords consisted of “public health” OR “population health” OR “community health”. The first group of search terms were combined with the second group to identify the studies.

The inclusion criteria were original studies in English language, published in a peer-reviewed journals from 1 January 2010 to 30 September 2017, with accessible full articles, that assessed the public health impacts on human health, which included either hospital-based and community-based studies. We excluded studies that were reviews or editorials, non-peer-reviewed review literature such as technical reports and web based guidelines and isolated clinical case study. The search strategy was summarised in Figure 1.

3.0Results and Discussion

A total of 165 studies were identified through the database searching. After primary screening and checking for the eligibility, 17 studies were included in this review. The results and discussion were categorised into morbidity, mortality, and burden of diseases related to heat waves.

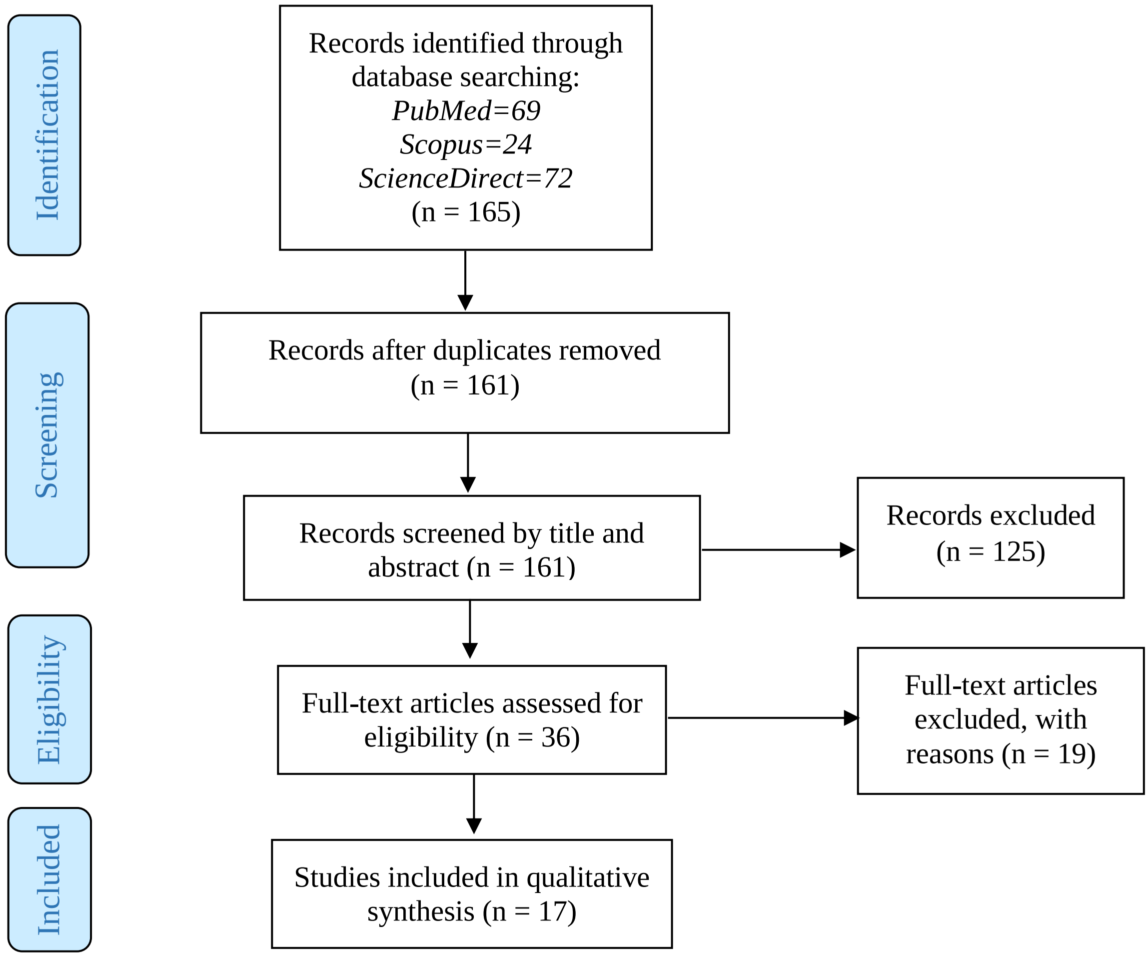

Figure 1: PRISMA flowchart for systematic search on public health impacts of heat waves.

3.1 Morbidity related to Heat Waves

Heat waves and extreme heat may result in several health morbidities to the community ranging from less severe of hay fever up to life threatening out-of-hospital cardiac arrest. The associated morbidity can be observed from hospital admissions due to heat-related conditions and kidney diseases, rate of emergency department visits, respiratory and asthma related hospitalizations. Findings from previous researches were summarised in the Table 1.

In addressing climate change health impacts, associations between climate and disease morbidity becoming one of the main research areas (Haines et al., 2006). Most vulnerable groups in developed countries such as elderly and people in poverty are mainly affected due to their weak capacity for adaptation. Extreme heat and heat waves health impact are more susceptible on the elderly such as hay fever and out-of-hospital cardiac arrest (Kang et al., 2016; Upperman et al., 2017). From health indicator reports on heat waves health effects between 2000-2016, the related morbidities were ranged from direct heat stroke and heat stress, to exacerbations of pre-existing heart failure and increased incidence of acute kidney injury secondary to dehydration in vulnerable populations (Watts et al., 2017). Hospital admissions due to heat-related conditions such as kidney diseases were shown to be sensitive indicators of heat waves (Xiao et al., 2017). These evidences signify that morbidity is more sensitive index than mortality in terms of the impact of extreme heat on population health (Bi et al, 2011).

Morbidity related to heat wave findings from the reviewed literature particularly affecting the urban centre of developed countries, which can be contributed by urban heat island effect and air pollution concentrations (Haines et al., 2006). There are still lacking of literatures looking on the health impact of climate change such as extreme heat and heat waves on the low-income countries even though they are mainly affected. WHO South-East Asia Region countries are particularly vulnerable to climate change of extreme weather events, under-nutrition and the spread of infectious diseases that can be projected to increase the mortality rates by 2030 if no further actions being taken (Bowen & Ebi, 2017). The observational records in most Asian countries are also insufficient to determine its annual precipitation trends over the past century, making it less comparable to other developed countries.

Heat waves can overpower human body by affecting its normal thermoregulatory mechanism in maintaining a constant core temperature for the body, which usually being coped by perspiring and breathing. As the temperature increased throughout the day and night in heat waves, the removal of body heat is impeded, while the body core temperature is increased (Robinson, 2000). Rapid increased in body temperature affect mainly the central nervous system and circulatory system, which can be manifested as confused, loss of consciousness, muscle cramps due to electrolyte imbalance, and renal impairment due to severe dehydration (Harmon, 2010).

Health indicators can be better measures of direct health outcome from climate change, apart from population exposure and vulnerabilities (Watts et al., 2017). As for extreme heat and heat waves health indicator, the challenge will be on the different sets of definition used by different country, and the source of data being collected. Most of the morbidity data reported in the reviewed literature were based on hospital admissions and emergency department visits via cross sectional study designs. This may limit the temporal causal effect of morbidity and heat waves. Hospital data may not represent Heat Stress Index in quantifying level of human discomfort accurately at individual's initial onset location as the catchment area of hospital in rural communities are usually larger compared to the city (Bishop-Williams, Berke, Pearl & Kelton, 2015). Local people and tourists' movement during summertime may also affect the hospital data representativeness. Defining loss of productivity based hospital stay duration can underestimate the total productivity losses of patients (Shao Lin et al., 2012). Their productivity losses are likely to continue even after being discharged from hospital, further explaining related health impacts projections.

Emergency department data could have been bias in sampling selection as there could have been unnoticed cases (Kang et al., 2016). The limited diagnostic information in Emergency Department can also prevent examinations of heat waves effects on population with different causes of ill health or air quality measures that can possibly interact with the heat waves intensity measures (Xiao et al., 2017). However, the accuracy of collected data from different sources in representing morbidity related to the extreme heat and heat waves was controlled in most of the studies by controlling important confounders such as hospital and regional location (Shao Lin et al., 2012;Bishop-Williams et al., 2015), time (Xiao et al., 2017), temperature, humidity, and air pressure (Kang et al., 2016).

Table 1: Morbidity Related to Heat Waves

MORBIDITY				
No	**Details**	**Title**	**Result**	**Remark**
1.	Author Xiao, J. et al. Year 2017 Design Retrospective Cohort	Variation in population vulnerability to heat wave (HW) in Western Australia.	i. Hospital admissions due to heat-related conditions and kidney diseases, and overall ED attendances, were sensitive indicators of HW. ii. Significant dose–response relationships between HW intensity and SES, remoteness, and health service usage (the more intense the HW, the higher the health service usage rates).	i. Did not include factors such as air quality measures and their potential interaction with heat waves intensity measures. ii. Did not include aboriginality as a risk factor (high rates of chronic kidney & cardiovascular diseases, and social disadvantages). iii. Did not adjust for the effect of green space on the health outcomes. iv. Limited diagnostic information in Emergency department prevented further examinations of heat waves effects on population with different causes of ill health.
2.	Author Upperman, C.R. Year 2017 Design Cross-sectional	Exposure to extreme heat events Is associated with increased hay fever prevalence among nationally representative sample of US Adults: 1997-2013.	i. Hay fever prevalence among adults 18 years and older during 1997-2013 was 8.43%. ii. Age, race/ethnicity, poverty status, education, and sex were significantly associated with hay fever status. iii. Adults in the highest quartile of exposure to extreme heat events had a 7% increased odds of hay fever compared with those in the lowest quartile of exposure (OR: 1.07, 95% CI: 1.02, 1.11).	i. NHIS survey does not collect exact data of onset of outcomes, degree of hay fever symptoms, or clinical indicators of allergen sensitization. ii. No information on local pollen levels, which can be explained the association between extreme heat events and reported allergies. iii. Cannot establish a clear temporality in exposure to extreme heat events and hay fever, and results may be affected by the length of time between exposure to extreme heat events and the recall of hay fever.
3.	Author Kang, S-H, et al. Year 2016 Design Cross-sectional	Heat, heat waves, and out-of-hospital cardiac arrest (OHCA).	i. Heat waves were shown to be associated with a 14-% increase in the risk of OHCA. ii. Adverse Effects were apparent from the beginning of each heatwave period and slightly increased during its continuation. iii. Excess OHCA events during heat waves occurred between 3 PM and 5 PM. iv. Subgroup analysis showed that those 65 years or older were significantly more susceptible to heat waves.	i. Some of the study cities had small numbers of cardiac arrests. ii. Sampling bias as OHCA cases were collected from the records of the emergency management service, there could have been unwitnessed cases. iii. Details on activities before the events were unavailable in this study.

MORBIDITY

No	Details	Title	Result	Remark
4.	Author Soneja, S. Year 2016 Design Time-Stratified Case-Crossover	Exposure to extreme heat and precipitation events associated with increased risk of hospitalization for asthma in Maryland, U.S.A.	i. Occurrence of extreme heat events in Maryland increased the risk of same day hospitalization for asthma (lag 0) by 3% (OR: 1.03, 95% CI: 1.00, 1.07), with a considerably higher risk observed for extreme heat events that occur during summer months (OR: 1.23, 95% CI: 1.15, 1.33). ii. Summertime extreme precipitation events increased the risk of hospitalization for asthma by 11 % in Maryland (OR: 1.11, 95% CI: 1.06, 1.17).	i. Exposure metric used was dichotomous in nature, and did not account for the intensity as well as duration of the event. ii. Spatial resolution of exposure metric was county level - potential for exposure misclassification with relatively small geographical area. iii. Use of the ICD code for asthma diagnosis could be controversial for those less than 4 years of age.
5.	Author Bishop-Williams, K.E. Year 2015 Design Cross-sectional	A spatial analysis of heat stress related emergency room visits in rural Southern Ontario during heat waves.	i. During a heat wave, the average rate of emergency room visits was 1.11 times higher than during a control period (IRR=1.11, 95% CI (IRR): 1.07, 1.15, $p \leq 0.001$). ii. When accounting for the confounding effect of a spatial trend polynomial in the hospital location coordinates, one unit increase in heat stress index (HSI) predicted an increase in daily emergency rooms visits by 0.4 % (IRR:1.004, 95% CI (IRR): 1.0005, 1.007, p=0.024) across the region.	i. HSI predicted at the hospital may not accurately represent the HSI predicted at the individual's location at the time of onset of illness. ii. Utilized preliminary data without personal identifiers or information about possible confounder which may result in overestimating the effect of heat stress on morbidity.
6.	Author Lin, S., et al. Year 2012 Design Cross-sectional	Excessive heat and respiratory hospitalizations in New York State: Estimating current and future public health burden related to climate change.	i. Estimated respiratory disease burden attributable to extreme heat at baseline (1991-2004) in NYS was 100 hospital admissions, US$644,069 in direct hospitalization costs, and 616 days of hospitalization/year. ii. Projections for 2080-2099 based on 3 different climate scenarios ranged from 206-607 excess hospital admissions, US$26-$76 million in hospitalization costs, and 1299-3744 days of hospitalization/year. iii. Excess respiratory admissions in NYS due to excessive heat would be 2 to 6 times higher in 2080-2099 than in 1991-2004.	i. Projections assume that associations between extreme heat and respiratory hospital admissions would remain constant over time (excluding possible physiological and behavioural adaptation). ii. Lost productivity based on the length of hospital stay under estimates of total productivity losses. iii. Size and demographic characteristics of each regional population assumed constant at baseline levels in future health impacts projections. iv. The accuracy of risk estimates of respiratory hospital admissions and the excess lengths of stay and costs related to extreme heat are uncertain.

3.2 Mortality related to Heat Waves

Heat can often exacerbate existing medical conditions and contribute to the increased risk of mortality. There are a number of factors which may modify or contribute to the mortality risk from heat, including social status, individual behaviour, the extent of urbanisation, and the influence of increased air pollution which may occur during hot periods. Given the complex interaction of these factors, the mortality count of each heatwave is very dependent on the event location, timing and past experiences of the local populations. We have reviewed 5 articles related to heat waves and mortality as presented in the Table 2. One important issue on heat waves that needs special attention are its impact on vulnerable groups. Our review has shown that heat waves has devastating impact especially towards elderly and women (Ahmadnezhad et al., 2013; Son et al., 2013). In the study by Bustinza et al. (2013), the average daily cardiovascular and respiratory mortality count of people over 65 years of age for the entire sampling period (2002 to 2012) was equal to 10.76. This was especially proven with the rise of elderly deaths during heat waves. This result confirms that the older people and women especially to be more sensitive on very hot temperature. Unfortunately both studies did not include children which are also considered in the vulnerable group. Significant attention needs to be given to efforts towards the reduction of mortality during heatwaves and very hot days, along with efforts towards the improvement of poverty and impacts on low-income families due to heat stress.

Heat waves are expected to appear more frequently and worsen with each passing year. Jackson et al. showed significantly more heat- and air pollution-related deaths to increase in the state of Washington. By 2025, projected warming would likely result in 101 additional deaths during heat events, and by mid-century, King County will likely experience 132 additional deaths between May and September annually due to worsened air quality caused by climate change (Jackson et al., 2010). A better understanding of climate change impacts on ambient air quality is critical to prepare for and alleviate potential worsened public health consequences where pathophysiology of heat stress causes loss of salt and water in sweat, subsequently promoting haemoconcentration, which in turn increases the risk of coronary and cerebral thrombosis. Other deaths in heat waves are probably due to overload of already failing hearts, unable to meet the need for increased cutaneous blood flow in the heat. Very few heat related deaths are caused by hyperthermia, overheating sufficient to cause denaturation of the body tissues which usually follows those who have underlying medical condition or those who are on certain types of medications (Cheung et al., 2000).

Mortality rates has proven to increase with events of heat waves. Paravantis J. et al. (2017) showed that mortality rated increased 20% to 35% respectively in high temperatures and very high temperatures respectively. Unfortunately, this study did not taken into certain factors that may contribute to such findings such as socio economic status of respondents. In addition to that, there was significant association between extreme temperatures and mortality rates (Zhang et al., 2014). One has to bear in mind that temperature events are unstable and may change from time to time without warning and understanding the characteristics of heat wave effects on mortality is important to better protect public health, particularly because heat waves will be more frequent, longer, and more intense in the future (Meehl & Tebaldi, 2004). Our findings suggest that mortality risk increased during heat waves in comparison to the communities' usual climates. The heat wave effects on mortality were affected by the intensity, but not duration. People living in moderate cold and moderate hot areas might be more vulnerable to heat waves than those living in cold and hot areas.

Table 2: Mortality Related to Heat Waves

MORTALITY				
No	**Details**	**Title**	**Result**	**Remark**
1.	Author Paravantis J. et al. Year 2017 Design Retrospective cohort	Mortality associated with high ambient temperatures, heatwaves, and the urban heat island in Athens, Greece.	i. Correlation of the daily cardiovascular and respiratory mortality count with various temperature measures confirmed a U-shaped exposure response curve, with fewer deaths in the range of moderate temperatures. ii. At high and very high temperatures, this mortality increased by 20-35%. iii. Multiple discriminant analysis: six clusters, with the highest excess mortality count of 23% for the cluster that included the hottest days and 20.6% for the heatwave cluster.	i. Other factors was not included; eg: socio economic status, occupation.
2.	Author Zhang J. et al. Year 2014 Design Retrospective cohort	Impact of temperature on mortality in three major Chinese cities.	i. The association between temperature and mortality was J-shaped, with an increased death risk of both hot and cold temperature in these cities.	i. The stability of temperature-mortality relation over time may change in the future. ii. Climate change is likely to produce extreme weather events, including more intense and frequent heat waves and cold spells. Study did not model effects of extreme weather events, and projections may underestimate or overestimate the impact of climate change.
3.	Author Ahmadnezhad E. et al. Year 2013 Design Ecological Time Series	Excess mortality during heat waves, Tehran Iran: An ecological time-series study.	i. Total excess mortality during 17 heat waves was 1069 (8.9 deaths/days). ii. All non-external cause of death increased significantly during heat waves (3-9%) and after adjusting for ozone and PM10 raised (RR:1.03, 95% CI: 1.01, 1.05 and RR:1.09, 95% CI: 1.07, 1.09 respectively). iii. Cause-specific deaths, especially circulatory disease, and death among elderly increased during heat waves, especially in the hottest wave.	i. Information Bias: Reports depend on heat waves definition and the reference period. ii. Classification of disease. iii. Ecological fallacy.

MORTALITY

No	Details	Title	Result	Remark
4.	Author Bustinza R. et al. Year 2013 Design Ecological study	Health impacts of the July 2010 heat wave in Québec, Canada.	i. During the heat wave, there was an increase of 33% for deaths and 4% for emergency department admissions in relation to comparison periods. ii. Mortality displacement (or harvesting effect) could not be studied in three of the eight health regions affected by the July 2010 heat wave due to the presence of other heat episodes in the 60 days following the impact period.	i. The study is based on the analysis of a single heat episode, which limits the generalization of results. ii. Difficulty in characterizing exposure in ecological studies. iii. Temporary death file. iv. Contains only coarse information about age and no information about the diagnosis, which limits further data interpretation. v. Analysis did not take atmospheric pollutants into account.
5.	Author Son J.Y. et al. Year 2012 Design Ecological Time Series	The impact of heat waves on mortality in seven major cities in Korea.	i. Total mortality increased 4.1% (95% CI: 6.1, 15.4) during heat waves, with an 8.4% increase (95% CI: 0.1, 17.3) estimated for Seoul. ii. Estimated mortality was higher for heat waves that were more intense, longer, or earlier in summer. iii. Estimated risks were higher for women, older, those with no education, and deaths that occurred out of hospitals in Seoul.	i. The analysis was based on a relatively small number of heat waves and deaths compared with other studies, and were not able to account for many potential confounding factors, such as levels of chronic disease. ii. The exact specification of a heat wave, and thereby estimates of heat-wave related mortality, vary among studies, and there are no standard criteria or models.
6.	Author Jackson J.E. et al. Year 2010 Design Retrospective Cohort	PH impacts of climate change in Washington State: Projected mortality risks due to heat events and air pollution.	i. Significant dose-response relationship between heat event duration and daily mortality rates for non-traumatic deaths for persons ages 45 and above. ii. Under the middle warming scenario, this age group is expected to have 96, 148, and 266 excess deaths in 2025, 2045, and 2085 respectively. iii. By mid-century in King County the non-traumatic mortality rate related to ozone was projected to increase from baseline (0.026 per 100,000; 95% CI: 0.013, 0.038) to 0.033 (95% CI: 0.017, 0.049). iv. The cardiopulmonary death rate per 100,000 due to ozone was estimated to increase from 0.011 (95% CI: 0.005, 0.017) to 0.015 (95% CI: 0.007, 0.022) in King County, and from 0.027 (95%CI: 0.013, 0.042) to 0.032 (95% CI: 0.015, 0.049) in Spokane County.	i. Unable to study the mitigating influence of such things as distribution of residential air conditioning or access to cooling at work or leisure. ii. Analysis considered only fatalities, the end stage of a progression of heat-induced morbidity that many individuals will not reach. iii. Complexities not considered in the analysis of ozone and mortality include differences within population subgroups regarding vulnerability, housing characteristics, and activity patterns which may vary in the future.

There were no added heat wave effects compared to the impact of high temperature on mortality in most countries. In addition, the observed variation in heat wave effects on mortality between communities/countries/regions indicates the importance of developing local heat wave response plans.

3.3 Burden of Diseases related to Heat Waves

Another way of supporting public health policy and action is looking at the burden of diseases in a population and this can be described by a variety of indicators as public health is a multifactorial phenomenon with many facets. In particular for this review, the burden of diseases related to heat waves looked into then hospitalization costs, willingness to pay (WTP), Disability Adjusted Life-Years (DALY), and socioeconomic factors.

Population determinants such as the socio-economic factors has probably been underrated in public health researches due to its complexity in methodology. However sociologist has often used this factors as a mean for predicting human and social behaviour. According to Rahman & Zakaria (2012) socioeconomic index is defined based on four variables namely poverty, homeownership, high school completion and unemployment. Based on the systematic review process, five articles were found fit to be discussed under this section (Table 3).

As heat wave is now considered an emerging public health stressors, the subtle effect noticed is the time change for physical activity where the public may increase night activity to avoid the heat and increasing opening doors and windows to promote overnight cooling. This was seen for the rural and remote communities in South Australia as they were aware of the country temperature changes and have taken adaptive measures towards its. However this created an issue concerning community safety. In particular for the rural and older population which are more heat vulnerable, this may decreased their physical acitivity and further restrict the social interaction which therefore may affect their overall morbidity status in terms of chronic illness, cognitive and mental health issues (Williams et al., 2013). Besides that, other socioeconomic disadvantages were the rising electricity cost, no transportation and the need for continuous education on how to avoid heat related illness were highlighted. In terms of occupational and environment factors, participant suggested for outdoor work rescheduling and providing infrastructure facilities as ‘cool public space’ is still limited.

In contrast to a study in Nigeria (Oloukoi, Bob & Jaggernath, 2014), the respondents (61.1%) were more aware of shortage water supply and sanitation issues as the contributing factors to their health. Coupled with poor access to physical infrastructure and healthcare services, communicable diseases became their main priority and the relation to climate change such as heat waves became unperceived. This is not surprising as Nigeria has higher percentage of poverty and local researchers have identified that climate issues will worsen the country’s situation in future if not tackled from now. This shows that having a sound knowledge on climate related issues such as heat waves and a policy integrating environmental health outcomes with multi-stakeholders involvement in sharing information related to heat waves will affects public behaviour on how to perceive and react, which will have further effect on population development.

Table 3: Burden of Diseases Related to Heat Waves

BURDEN OF DISEASES				
No	**Details**	**Title**	**Result**	**Remark**
1.	Author Zhang, Y. et al. Year 2016 Design Cross-sectional	Willingness to pay for measures of managing the health effects of heat wave in Beijing, China: A Cross-sectional survey.	i. Overall, more than 1/3 of respondents WTP with approximately CNY40 per year for protective measures against heat wave. ii. Likelihood of WTP were based on significance level, *p*<0.1 were: • 2.39 times more among higher income group (*p*< 0.001) • 1.25 times being female (*p*=0.07) • 1.71 times with past experience of heat wave (*p*=0.01) iii. Based on logistic regression, the only significant factor remained was individuals with past experience of HRI (OR: 1.79, *p*=0.01).	i. Questionnaire had respondent bias with the concept of WTP varies between researches. ii. The discussion on the strength of OR was limited to the significance value that the reseacher used as *p*<0.1 and the 90% Confidence Interval was not provided in the article. The researcher chosed a less stringent significant p value may be because of the large sample size.
2.	Author Schmeltz, M.T. et al. Year 2016 Design Retrospective Cohort	Economic burden of hospitalizations for heat-related illnesses in the United states, 2001-2010.	i. Length of stay for heat related illness was relatively shorter compared to all hospitalization [2(1-3); 3(2-5) days respectively]. ii. Hospitalization cost were greater among female, aged>40 years, among the non-White population-Blacks, Hispanics & Asian with mean cost more than USD1000 per hospitalization (p<0.01). iii. Higher cost particularly for those in the lower socioeconomic area and having no insurance (p<0.05 using Tukey's HSD test).	i. Patient diagnosed as heat-related illnesses but treated as outpatient was not captured in to the census. ii. Patient information bias as only rely on coding and diagnosis given (patient confidentiality). iii. Cost related to rehabilitative therapy was not included.
3.	Author Yoon, S-J. et al. Year 2014 Design Retrospective Cohort	Measuring the burden of disease due to climate change and developing a forecast model in South Korea.	i. During heat wave, DALY of hypertensive heart diseases (1.82/1000 population) outweigh IHD and cerebrovascular diseases (1.56/1000 population). ii. Estimation model predicted that disease burden due to climate change will increase to 11.48 DALY/1000 population in 2100.	i. Calculation of burden of disease was not comprehensive enough. ii. Estimation took into consideration the meteorological factors only. Socio-economic-political influences was not accounted for.

BURDEN OF DISEASES				
No	**Details**	**Title**	**Result**	**Remark**
4	Author Oloukoi, G., Bob, U., and Jaggernath, J. Year 2014 Design Cross-sectional	Perception and trends of associated health risks with seasonal climate variation in Oke-Ogun region, Nigeria.	i. About 61.1% of the communities were aware of health effects were due to shortage, unimproved water which was common during dry season. ii. In addition, poor access to physical infrastructure and healthcare services, communicable diseases became their main priority and the relation to climate change such as heat waves became less apparent. iii. Burden of disease due to heat waves may be under-reported as self-prescription and alternative healing is a common practice. iv. Children and women were identified as vulnerable group to stressors related to climate variability.	i. The sample size (N= 397) may not be sufficient as it was further stratified into three groups based on locations (n=125, 104, 168). Statistical adjustment or correction was not mentioned. ii. The association of health risk to healthcare services was due to accessibility factor rather than climate change effect.
5.	Author William, S., et al. Year 2013 Design Qualitative	Extreme heat and health: Perspectives from health service providers in rural and remote communities in South Australia.	i. Reduced quality of life and social isolation due to becoming housebound especially for the elderly. ii. General population increases night activity and opening the doors and windows to promote better ventilation but backfires with major concern of community safety. iii. The rising cost of electrical usage affecting the rural and poor. iv. Other socio-economic disadvantages were housing, transport, and geographical.	i. Could not be compared to other quantitative studies. ii. Explanation on the reasons for issues highlighted gave deeper meanings.

When discussing the effect of heat waves and how much public is willing to pay or prevail upon goods/things to avoid undesirable effect basically define the concept of one's willingness to pay (WTP). A research by Zhang et al. in 2016 who studied 1210 individuals in Beijing, China on their WTP for heat wave protective measures such as an early warning system, enhancing municipal infrastructure and public education found that generally they are willing to pay up to 40 CNY per annual capita while more than half is still dependent on government support. Additionally based on the researcher's only information available on the chosen significance value level of 0.1, those of the middle economic status was 2.39 times more WTP for these protective measures, being female (OR 1.25, $p=0.07$), having air conditioner at home (OR=1.42, $p=0.05$) and past experience of heat waves (OR 1.75, $p<0.01$) had greater WTP. With further logistic regression, unfortunately only individuals with past experience of HRI (OR 1.79, $p=0.01$) remained the significant factor within the model. In general, based on the analysis of the Healthcare Cost and Utilization Project (HCUP) of the United States, the length of hospitalization for heat related illness (HRI) was relatively shorter compared to all hospitalization with median (IQR) of 2(1-3) days and 3(2-5) days respectively (Schmeltz, Petkova & Gamble, 2016). Despite hospitalization of HRI being short and having lower overall total charges, there is still higher disparity and greater burden of cost with mean cost exceeding over USD1000 per hospitalization especially for older aged respondents, non-White population (Blacks, Hispanics and Asian) as well as those living in the lower zip-code income quartile and with no insurance coverage. Even though this study had few limitation, it may serve as a basis for other future researches planning to perform cost effective intervention especially for the underprivileged population.

Apart from the above mentioned, information on other measures of overall burden of disease includes the disability-adjusted life years (DALY) where WHO has defines it as loss of the equivalent of one year of full health and this calculation can relatively be compared with other diseases in terms of causing disability. According to a study that investigate the cause of mortality of South Korea, heat wave was identified as the risk factor to certain diseases such as hypertensive, cerebrovascular and ischaemic heart diseases. The DALY was calculated based on disease burden data for the year 2008 through a computer modelling and coupled with the population attribution fraction of temperature as a proxy to heat wave exposure. It was found that DALY due to heat waves was 1.82 per 1000 population and accounting more than 30% of the total DALY with hypertensive heart disease as the greatest disease burden (Yoon et al., 2014). When comparing with the global disease burden by WHO in 2009, the DALY for hypertension was 3.8 per 1000 population.

4.0 Conclusion and Recommendation

In conclusion, heat waves can result in significant public health impacts related to morbidity, mortality, and burden of diseases. Similar vulnerable factors such as gender, population income, poverty, and living condition were identified in majority of the articles reviewed. More efforts are needed to increase the capacity of health systems to manage the health risks of climate change in low-income countries particularly, if population health is to be protected and strengthened. In order to do this, future researches need to include relevant variables not only the meteorological and environmental data but also variables of disease burden, hospitalization and its direct and indirect costing. The data of adverse climate-sensitive public health impacts are crucial in effective design and implementation of preventive programmes.

Subsequently public health professionals need to act urgently in addressing climate change and planning for a long-term adaptation to reduce mortality and morbidity of heat waves.

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Declaration

The authors have no conflict of interest for declaration.

Authors' contribution

Author 1-4: Literature search, analysing, writing, drafting and editing the manuscript.
Author 5: Idea and concept as well as reviewing final manuscript.

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