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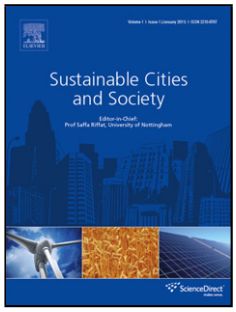

Title: ADAPTATION STRATEGIES FOR MINIMIZING HEAT WAVE INDUCED MORBIDITY AND ITS DETERMINANTS

Authors: Khuda Bakhsh, Sara Rauf, Farhad Zulfiqar

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ADAPTATION STRATEGIES FOR MINIMIZING HEAT WAVE INDUCED MORBIDITY AND ITS DETERMINANTS

Khuda Bakhsh, Department of Management Sciences, COMSATS Institute of Information Technology, Vehari campus, Pakistan

Sara Rauf, Institute of Agricultural and Resource Economics, University of Agriculture, Faisalabad-Pakistan

Farhad Zulfiqar, Department of Management Sciences, COMSATS Institute of Information Technology, Islamabad campus, Pakistan

Corresponding author's email. Khuda Bakhsh kbakhsh@ciitvehari.edu.pk

Highlights

- Adaptation to heat waves and its impact on human health are explored.
- Those adapting to heat waves are relatively less probable to experience heat-related illness
- Income level, family size, males in a house and adaptation are significantly related with the number of patients suffering from heat waves

Abstract

Heat waves pose serious health threats to human mortality and morbidity in many countries, including Pakistan. There are various factors that contribute towards heat wave induced morbidity and several adaptation measures are at disposal to avoid adverse effects on human health. This research was designed to examine different adaptation measures taken by the respondents and to estimate the determinants of heat wave induced morbidity. The sampling design consisted of primary data collection from 251 respondents in urban and peri-urban areas

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of Faisalabad, being one of the big cities in Pakistan, using a pre-tested questionnaire. The most common adaptation strategies were identified and an index of adaptation strategies was generated. The determinants of the number of patients in a family suffering from heat waves were estimated using Poisson regression model. The research findings revealed approximately the same adaptation scores of both urban and peri-urban respondents indicating no differences in adaptation level of both groups. The most commonly used adaptation strategies during heat waves included using plenty of water, and juices, increasing the number of baths, using an umbrella, cloth/cap, wearing sunglasses, and using green sheets/chicks in the house. The most important and statistically significant determinants of heat wave induced morbidity were the adaptation to heat waves (captured by adaptation score), urban/peri-urban background, family size, the number of males, and high income. Thus, it was concluded that the adaptation practices have strong health implications in the face of health challenges posed by heat waves. Based on the research findings, it is suggested that the health policies aimed at reducing the health impacts of heat waves may focus on awareness campaigns on available adaptation strategies through different media sources, widening access to health facilities, and extending swimming facilities particularly in urban areas. These strategies are important policy interventions to reduce vulnerability of population to heat waves.

Keywords: Heat waves; Thermal adaptation; Health impacts; Morbidity; Urban heat island effect

1. Introduction

Frequency, intensity and duration of climate change induced natural disasters pose serious threats to human health due to increasing frequency of occurrence (Mirza, 2003). Flood, earthquake, heat waves and drought kill thousands of people each year in the world (Strömberg,

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2007). Alone, heat waves cause several morbidity and mortality in the world and Pakistan is no exception. The climate change has exacerbated the effects of heat waves (Lowe et al., 2011). The year 2003 has the worst record of deaths caused by heat waves in the Western Europe when 70000 deaths were reported (Robine et al., 2008). Nearly 15000 deaths in Russia in 2009 (Dole et al., 2011) and 500 deaths in Australia in 2011 (Akompab, 2013) show the intensity of health impacts of heat waves.

Many developing countries are facing the challenges of heat waves. In India, 3000 deaths were reported in 2003 (Das and Smith, 2012). The situation in Pakistan is also alarming, where 65000 individuals were taken to hospitals for the treatment of heat stroke in Karachi due to heat waves in 2015 (Glum, 2015). The plain areas of Pakistan are also experiencing the effects of heat waves. In the early May of 2013, above 100 deaths were reported in the plain areas of Pakistan (Sheikh and Tunio, 2013). The effects of heat waves become further critical in the presence of the limited health facilities in the country.

People of all ages are vulnerable to adverse impacts of heat waves. However, the older individuals are at higher risks of heat wave-related morbidity and mortality (Abrahamson et al., 2008; Hansen et al., 2011; Son et al., 2011). Similarly, people suffering from heart and lung problems are more vulnerable to heat waves (Kosatsky et al., 2009). Individuals even suffering from any health problems are more susceptible to be affected from heat waves (Kovats and Hajat, 2009). Kolachi et al. (2008) argue that male farmers and laborers are highly vulnerable to heat waves.

Knowledge and perception of heat waves lead to adapt to fatal calamity. Very few people have knowledge-built perception on heat waves in Pakistan (Rauf et al., 2017). Mostly, people do not consider themselves to be exposed to heat waves. People seldom use protection measures and

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they, therefore, face greater risk of heat waves related morbidity and mortality (Bouchama et al., 2007). Individuals perceiving risks associated with natural disasters are highly induced to adaptation to climate related health hazards (Grothmann and Patt, 2005). Knowledge of laymen on adaptation to climate change related disasters is unknown until they experience disasters (Neumayer et al., 2013) and literature on climate change suggests that shocks and weather fluctuations update people's perception and awareness of the natural hazards (Gallagher, 2014; Deryugina, 2013).

Adaptation to heat waves is the strategy to reduce the impacts on human health by reducing the vulnerability to severity of heat waves (Hassan and Nhemachena, 2008; Falco et al., 2011; Kaleon et al., 2013). Hence, adaptation is the most important way to avoid or reduce heat waves related health impacts. People can reduce the impact of heat waves on health by avoiding or reducing exposure to heat waves and adapting infrastructure designs (Menne and Matthies, 2009). Basu (2009) and Menne and Matthies (2009) found a U or J shaped relationship between temperature and deaths at an optimal temperature, since temperature below optimum causes cold waves and above the optimum level results in heat waves. In both cases, adaptations are required to minimize the health effects. Nitschke et al. (2007) found no extra heat related morbidity for individuals who adopted the adaptive measures. Access to finance, improved advisory services and availability of electricity also contribute in adaptation (Hassan and Nhemachena, 2008; Falco et al., 2011). Deressa et al. (2011) found education level, household size, gender and temperature as the important determinants of adaptation. Similarly, age, occupation, and heat waves related knowledge are among the strong factors of heat waves related adaptation (Zhi-hui et al., 2013). An efficient warning system relating to the heat waves and other extreme events is also important in reducing the risk on human health. Das (2016) showed that television was the

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more effective source of creating awareness in India. This warrants for corrective measures to be taken for generating awareness among the masses. For achieving this end, having knowledge on factors affecting adaptation to heat waves is crucial for making an effective and efficient policy on heat waves (Sherwood and Huber, 2010).

The concern relating to health implications of heat waves is growing in the world including Pakistan. Nasim et al. (2018) projected heat waves will affect Southern Punjab and Sindh provinces of Pakistan in the coming years. They also found a rising trend of heat waves over the period of 1997-2015 for Balochistan, Sindh and Punjab. In such circumstances, adaptation to heat waves becomes crucial to reduce the risk on human health. Health benefits of adaptation to heat waves have become attractive to the policymakers. However, understanding factors affecting adaptation is important to devise evidence based policies for reducing or avoiding the health risks resulting from heat waves. Further, it is also important to examine the impacts of adaptation to heat waves on morbidity. Although a few studies are available in the context of Pakistan examining the trend of heat waves, knowledge, perception and adaptation to heat waves (Nasim, et al., 2018; Bakhsh, et al., 2016; Rauf et al., 2017), there is limited research focusing on the impact of adaptation on morbidity. According to IPCC (2012), strategies to reduce the risk of natural hazards such as heat waves is an important part of climate change adaptation. Further, the information on the impact of adaptation to heat waves on morbidity provides the useful insights to design and formulate strategies to reduce the adverse impacts of heat waves. The present study bridges the information gap by examining adaptation to heat waves and assessing the effects of adaptation on morbidity in metropolitan area of Pakistan. The study hypothesize that adaptation to heat waves tends to reduce the vulnerability of the risk relating to heat waves. We collected information on socioeconomic characteristics, adaptation and morbidity relating to heat waves

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from urban and peri-urban dwellers of one big city of Pakistan which is highly exposed to heat waves due to urban heat island effects (Zahid and Rasul, 2010; Saeed and Suleri, 2015). Findings of the study provide a caution for generalizing results to urban and peri-urban Pakistan. Perception level and adaptation strategies among the decision makers are important for devising policies relating to heat waves and human health (Reischl et al., 2016). The present study is expected to provide this information to the concerned policymakers and others involved in the early warning system campaign.

The remaining research article is divided into five sections. The next section describes literature on heat waves and the impact on human health. Empirical method and source of data are given in fourth section. Fifth section is allocated to findings of the study, followed by discussion section. The last section concludes the study.

2. A brief literature review

Healthy society has crucial role in the economic growth of any economy on sustainable basis. However, sustainability is at the risk of climate change related extreme events such as flood, drought, earthquake, and heat waves. Although other extreme events cause havoc to urban cities and societies, heat waves are increasing in many parts of the world during the last decade and hundreds of deaths recorded in Europe and Russia indicate the intensity of the problem. WMO (2013) reported an increase of 2300 folds in the death rate from the last decade of 20^{th} century to the firs first decade of 21^{st} century. Extreme weather events such as temperature and heat waves contribute around 20% in death rate (Lu and Chen, 2016). Mega cities are highly vulnerable to the risk of heat waves as a result of urban heat island effects phenomenon. Kikon et al. (2016) and Mehmood et al (2016) report an increase of temperature from 2 ^{o}C to 3 ^{o}C during the last 15 years in the big cities of India and a rise in temperature is linked with heat accumulation. This is

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evident from the fact that high causality from heat waves is reported from Central and south eastern India and central parts of Pakistan in the recent years (Jaswal, et al., 2015; Mueller, et al., 2014; Panda et al., 2014).

Heat waves are associated with risk of heat strokes, health diseases and disturbance in settlement (Maida and Rasul, 2011; Haider et al., 2008; Rasul et al., 2005). Mental disorder related hospital admission increased during the heat waves in Hanoi, Vietnam and the risk was positively related with the length of the heat waves (Dholakia and Amit, 2014).

Heat waves have the adverse effects on urban environment and human health, threatening sustainability of urban environment. Ariane et al. (2013) find the larger effects of heat on air pollution thereby effecting mortality and morbidity compared to the direct effects of heat waves on human health. Umoh et al. (2013) found a largely heterogeneous mortality risk relating to increasing intensity of heat waves in different urban cities in India. Even the developed nations with adequate health infrastructure and air conditioning facilities are no exception to the risk of mortality and morbidity related to heat waves. Like Europe and Russia, USA observed a 7% increase of hospital admission during the peak heat waves in California (Guirguis, et al., 2014).

There are many studies available in the literature focusing on the impacts of heat waves on human health (Das, 2016; Das and Smith, 2012; Martiello and Giacchi 2010; Basu and Samet 2002). However, intensity of heat waves and the impacts on human health vary across regions. Thus the need is to investigate the risk of heat waves on human health and the related warning system to be developed regionally (Barnett et al. 2010; Bobb et al. 2011; Vaneckova et al. 2011). The present study was designed to add the value in the literature by conducting a study in the densely populated city of Pakistan.

3. Materials and Methods

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3.1 Source and Data

The study sample was selected through multistage random sampling. At first stage, Faisalabad district from Punjab province of Pakistan (Figure 1) was purposively selected for the present study because of its climate and population. According to the Koppen-Geiger system, the climate of Faisalabad is classified as the BWh and the hot desert climate prevails in the city with virtually no rainfall during the year. Faisalabad is among the hottest cities of temperate zone with long summers, short winters and frequent heat waves. Zahid and Rasul (2010) and Saeed and Suleri (2015) reported an increase in heat waves in future in many big cities including Faisalabad district. Saeed and Suleri (2015) found that densely populated cities would be vulnerable to adverse effects of heat waves and Faisalabad is the third largest city of Pakistan. Nearly eight million people reside in this district (PBS, 2018) with more than 100 operational textile, garments and other industrial units. Labor force employed in the industrial units comes from the peri-urban of Faisalabad who are at higher risk of heat waves due to their frequent commuting. However, the meager public health infrastructure is insufficient (Rauf et al., 2017).

At the second stage, urban and peri-urban areas were selected randomly from Faisalabad district. Peri-urban areas are rural-urban transition zones where urban and rural areas mix. Peri-urban areas are also called surroundings of the urban areas or suburb areas whereas urban area is defined as the human settlement with high population density and infrastructure for providing utilities to the dwellers. The data collection was made separately for the two groups because urban areas are highly susceptible to the effects of heat waves as a result of “urban heat island effect” phenomenon (Saeed and Suleri, 2015). Therefore, the present study focused on both urban and peri-urban areas. The next stage included selection of the respondents through a purposive and systematic random sampling method in proportion to the population of urban and

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peri-urban areas. Towns and urban and peri-urban strata were purposively selected. Every third house was selected in the selected town using systematic sampling technique to select a respondent. A list of the adult individuals (above 18 years) was made for each selected house. The respondents were selected at random from the list. The sample consisted of 251 randomly selected respondents, of which 150 were urban and 101 peri-urban. Farm workers, farmers, daily wagers, household women and students (above 18 years age) were interviewed from the peri-urban areas. Professionals, daily wagers, employees of public and private organizations, housewives and students (above 18 years age) were interviewed from the urban areas.

The selected respondents were interviewed using a well-structured and pre-tested questionnaire. The questionnaire was administered by person and the second author personally visited the selected respondents and asked the respondents to respond to the questions given in the questionnaire. Although the questionnaire was prepared in English, the questions were asked in the local language of the respondents. Questionnaire included information on socio-economic characteristics, knowledge relating to heat waves along with the effects, adaptation to heat waves and impact of adaptation on human health (Appendix 1). Considering the compliance to important research aspects, the Thesis Scrutiny Committee of Faculty of Social Sciences, University of Agriculture, Faisalabad approved survey, survey design and ethical issues.

The respondents were inquired about the adapted preventive measures to heat waves. For this purpose, we asked the respondents to provide their response on different practices relating to adaptation to heat waves. A total of twelve statements were included. Scores of all statements were added to assess the adaptation scale among the respondents. Positively worded statements were ten and negatively worded statements were two. An example of negatively worded statements is *"Go to shopping or meeting relatives during the peak hours of heat waves"* and an

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example of positively worded statements is *"Use an umbrella/cloth/cap when going outside"*. We assigned score of one for never, two for somewhat and three for always in case of the positive statements. We reversed these scores for negative statements. Added scores of all the statements were dichotomized at mid-point to divide adapters into poor and good adapters (Table 1).

3.2. Empirical method for estimating the adaptation impact on human health

The present study examined the adaptation to heat waves and its impact on morbidity by asking the respondents to provide information on the incidence of health problems among the household members. Descriptive statistics were used to compare adaptation to heat waves in urban and peri-urban Faisalabad.

Considering the impact of adaptation on morbidity, the number of individuals suffering from heat waves during the last year was taken as the dependent variable. There can be so many reasons for morbidity, in addition to heat waves. For making confirmation, the respondents were asked whether morbidity occurred as a result of the exposure to heat waves and the doctor confirmed it during the medical examinations. The number of patients due to heat waves is a count variable with few small discrete values. Employing a logit/ probit model undermines the total counts of the variable (Piza, 2012) because of collapsing several counts into a single value thereby reducing the validity of the model. Therefore, Poisson and negative binomial models were the appropriate options for the count data dependent variable having rare occurrence of the events.

The selection between Poisson and negative binomial model depends on the assumptions of conditional mean and variance. The Poisson model assumes equal distribution of the conditional mean and variance (equidispersion) and negative binomial regression does not assume

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equidispersion (Osgood, 2000; Piza, 2012). Thus, Pearson Chi-square goodness of fit was used to choose the best model among the available options for the given data (Piza, 2012). The Pearson goodness- of- fit test confirmed a Poisson distribution with a p-value of 0.1763. Hence, Poisson model was employed in the present study.

The number of patients constituted the count dependent variable in the present study. Explanatory variables included adaptation to heat waves, background of the respondent, family size, schooling years of household head, income level of the respondents and number of males in the house. Poisson model is as under

$$P_n = \delta + \delta_1 A_i + \delta_2 W_{1i} + \delta_3 W_{2i} + \delta_4 W_{3i} + \delta_5 W_{4i} + \delta_6 W_{5i} + \mu_i$$

Whereas P_n is the number of patients due to heat waves in a household. *A* shows adaptation level to heat waves[1] as defined in the earlier section. It was a dummy variable, taking a value of one for good adapters and zero for poor adapters. Individuals using different types of adaptation measures were expected to be less vulnerable to heat waves. W_1 represented background of the respondent in the form of a dummy variable. It took the value of one if the respondent was urban and zero for peri-urban household. This variable was taken to see the urban heat island effect phenomenon. Family size of the household in the form of number of household members was represented by W_2. The large family size may have negative effect on morbidity cases as the households with large family size may have the advantage of completing tasks well in time and, therefore, less exposure to heat waves. W_3 showed schooling years of the head of the household. Households with more education are expected to adapt preventive measures because of having access to information and higher level of awareness. W_4 represented income level of the households whereas the number of males in the household was shown by W_5. The number of

[1] For detail information on adaptation level and its estimation procedure, see Rauf et al. (2017)

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males in a household was taken to consider the role of the earners on adaptation to heat waves thereby resulting in better human health. μ_i represented the usual error term with zero mean and constant variance. Table 1 showed the summary statistics of the variables used in the Poisson model. Score of adaptation to heat waves in urban and peri-urban areas was almost the same. Out of total respondents, 60% respondents were from the urban areas of Faisalabad. Family size was relatively large for the peri-urban respondents. Schooling years among the urban households was higher than the peri-urban respondents. The respondents from peri-urban households had comparatively low income compared to the urban households.

Table 1 approximately here

4. Results

4.1 Adaptation to heat waves and impact on human health

The present study was designed to examine the adaptive behavior of the respondents. Figure 2 provides information on the responses of the respondents relating to following the news relating to heat waves and preventive measures. Such information is provided through electronic and print media. This figure shows that 21% respondents from the peri-urban area were not found following the information compared to 11% of the respondents from the urban area. Further, we considered different responses in the questionnaire relating to adaptation to heat waves. We asked the respondents to give their responses in three forms; 'always', 'sometimes' and 'never'. Table 2 shows the responses provided by the respondents. The 'always' response in all 12 statements was higher for the statement of *'drink plenty of water to stay hydrated'* as 89.3% respondents of urban Faisalabad and 91.1% of the peri-urban Faisalabad used this adaptation practice. Another highly adapted behaviour by the urban and peri-urban respondents as 'always' was '*increase the number of baths'*. Other important responses relating to 'always' adopted

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behavior were '*Seek protection of shady areas when out of home'* and '*drink more milk, juices, kachi lassi, and so on'*. The "never" response relating to *"go to shopping or meeting relatives in the peak hours of heat waves"* was found 64% among the urban respondents. The higher percentage with "never" response relating to '*use sun-block or sunglasses'* was 59% among the peri-urban households. Most adaptation practices were similar in both urban and peri-urban households. However, disparities were noted in practices such as seeking shade when away from home, outing in peak hours, and use of sunblock/ sunglasses (Table 2).

Table 2 approximately here

Table 3 shows the heat wave impact intensity on respondent who were affected by heat waves and were hospitalized. Figure 3 indicates the heat wave impact intensity on human health in the sample. Special attention was given to find the number of heat-related illness among the respondents. Only those cases were considered in the present study where the respondents reported the exposure to heat waves as the cause of illness and the doctor confirmed it to the respondents during the medical examinations. In the urban area, 41% respondents reported that they suffered from heat waves during the last summer. Among them, 10% were hospitalized. In peri-urban areas, the percentage was comparatively less compared to urban areas, as around 36% respondents experienced the illness and overall it was 38.6% in the study area.

Table 3 approximately here

The adaptation to heat waves was expected to reduce the negative impacts. This impact of adaptation to heat waves was measured in the form of reduction in the intensity of illness. In the urban area, 57.4% of the poor adapters recorded suffering from heat waves as compared to

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42.6% of the good adapters. Whereas, 63.9% of the poor adapters suffered from heat waves compared to 36.1% of the good adapters among the peri-urban respondents (Table 3). In the peri-urban area, 55.6% of the poor adapters experienced heat related illnesses as compared to 44.4% of the good adapters. On the basis of overall sample, 59.8% patients suffered from heat waves were poor adapters (Figure 3). Further, the good adapters were found having comparatively higher education level (schooling year) with small family size compared to the poor adapters (Figure 4). Thus, the good adapters were able to withstand heat waves better than poor adapters in both urban and peri-urban areas.

4.2 Relationship between adaptation and morbidity: results of Poisson model

Poisson model was used to determine the impact of adaptation and other factors on number of patients suffered from heat waves. The effect of adaptation on number of heat related patients was significant and had a negative sign. The number of patients, caused by heat waves, from urban residents was 1.30 times higher than those who were residents of peri-urban areas. As the family size of the respondents increased the number of patients due to heat waves increased by 14%. The respondents from high income group had 83% less number of patients compared to the respondents with low income. Number of males in a house was negatively related with number of patients due to heat waves.

Table 4 approximately here

5. Discussion

Population exposed to heat waves takes various adaptation measures. These measures vary across individuals and location. Understanding adaptive behavior of individuals to heat waves is important in designing policies seeking awareness among the masses and building capacity for avoiding adverse effects of heat waves. The present study addressed this issue by studying

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different measures taken by the respondents during heat waves. Taking plenty of water to be hydrated was the most commonly measure taken by urban and peri-urban respondents.

Using umbrella, cloth or cap was rarely used by by the respondents. This measure is relatively more common among the peri-urban respondents compared to urban respondents. However, many respondents are found using no umbrella or cloth while going outside. Cost of umbrella/cloth was the reason for not using this preventive measure particularly among the peri-urban respondents as these are daily wagers and have little income to purchase umbrella, and other personal protective measures. Liu et al. (2013) also found that individuals with income constraints were not able to afford costly adaptation practices. Further, job nature of peri-urban respondents also exposed them to heat waves as Bakhsh et al. (2016) showed that 53% peri-urban workers perform their duties in open field, particularly in agriculture fields and commute time to work place was also statistically higher than urban respondents.

Using air conditioner/air cooler during heat waves is considered critical option to avoid adverse impacts of heat waves on human health. However, the use of air conditioner/cooler was rare among the urban and peri-urban respondents. Although some respondents reported having these appliances, the use was sparse due to high utility bills. The respondents were not able to afford utility expenses due to the limited income. This necessitates the energy efficient cooling appliances at low and affordable prices to the dwellers. However, low energy cost is associated with an increase in energy demand and Pakistan is already facing huge energy shortage, particularly during summer (GoP, 2016). Employing renewable energy sources such as solar panel at subsidized prices is possible strategy to lower energy demand. Insulation of ceiling and walls is another possible measure for reducing the effects of heat waves. The respondents in

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urban and peri-urban areas used green sheets[2] to lessen the impact of heat waves. Green sheets are used as a substitute of insulation of ceiling and walls as green sheets are less costly than insulation.

The respondents from urban areas suffered more from heat waves compared to peri-urban respondents, mainly because of *"urban heat island effect"* phenomenon. Thus, cases of hospitalization were relatively higher among the urban respondents. However, adapting to heat waves reduced the chances of heat related illness. The concentration of illness further decreased for good adapters (Table 3).

Adaptation to climate change reduces the adverse effects of the disastrous weather events on human. Similarly, adapting to heat waves reduces the severity of its impacts on human health (Hassan and Nhemachena, 2008; Falco *et al.*, 2011; Kaleon *et al.*, 2013). Considering the impacts associated with heat waves, the onset of the effects is slow and households generally do not perceive them with little knowledge of the health impacts of rising temperature. Heat strokes, dehydration and mild nervous breakdowns are some of the impacts of heat waves on human health (Bi et al., 2014; Woodruff et al., 2006). Some other impacts of heat waves on human health include stresses accompanied by sleeplessness, lethargy and general abnormality (Hansen et al., 2008). Page et al. (2007) found that acute or chronic mental problems triggering episodic psychological distress and irritability resulted in the presence of no relief from extended heat period. Further, children and the aged persons are generally highly vulnerable to high summer temperature, so the ailments and deaths increases among this segment of population due to heat shocks (Bi et al., 2014). This is particularly important in the context of developing countries, including Pakistan, with weak health protection infrastructure and poor health facilities. Thus,

[2] Households use green sheets made of green cloth and supporting material to lessen the effect of heat energy

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generating awareness on adaptation to heat waves is the key to reduce the health impacts of heat waves in the short-run.

Poisson model was employed to find out the factors affecting number of patients suffering from heat waves. As expected, adaptation to heat waves was significantly related with number of patients. The findings revealed that the number of patients decreased by 86% as the respondents used adaptation practices to heat waves. Similar results showing positive effects of adaptation on human health have been reported elsewhere (Brewer *et al.*, 2004; Hassan and Nhemachena, 2008; Falco et al., 2011; Kaleon et al., 2013).

Another important factor affecting the number of heat wave related patients was family size. The households with large family size were more exposed to heat waves as this large family size may include many children and the elderly people. Children and the elders are highly vulnerable to heat shocks (Bi et al., 2014).

The income level of the respondents was significantly and negatively related with the number of patients in the house. Individuals from high income group were found having 83% fewer patients compared to the low income group indicating that individuals with high income were able to afford different cooling appliances whereas the individuals with low income find it difficult to use such appliances during summer (Liu et al. 2013). The respondents with low income barely make ends meet and, thus, unable to invest on adaptation to heat waves.

The number of males in the house also plays an important role in determining the patients in the house. As the number of males in the house increases, the chances of heat affected patients reduces by 90%. This is because of the fact that with an increase in number of males in a house, number of the earners also increases. This results in an increase in family income. Such respondents make investment on adaptation to heat waves, as they are able to purchase costly

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appliances such as air conditioner, cooler, and so on. They can also afford to make a change in their working time. Low income and the number of males in the household can be related. However, we found very low score of correlation coefficient between these two variables and it was statistically non-significant.

Location of the respondents also matters as the impact of heat waves varies across locations. The urban respondents were found to have higher exposure to heat waves compared to peri-urban residents (Table 4). Faisalabad city is densely populated and the impacts of heat waves are, therefore, many folds in the urban areas compared to the peri-urban areas. This result confirms "urban heat island effect" phenomenon. Zahid and Rasul (2010) and Saeed and Suleri (2015) also reported that the big urban centers were more exposed to the adverse effects of heat waves and Faisalabad is the second largest city of the Punjab province of Pakistan.

Considering one district does not seem to represent urban and peri-urban Pakistan when sample size is 251. Green (1991) and Algina and Olenjnik (2003) report that sample size of 200 or above is good enough to understand the realistic picture of behavior of population residing in the urban areas. Thus the findings of the study provide sufficient evidence on the adaptation practices and the resultant impact on human health. The characteristics of Faisalabad are similar to other cities of Pakistan and many developing countries as well. Insights provided by the study are useful for densely populated cities of Pakistan in particular and developing countries in general for making policies on adaptation to heat waves and heat wave-related morbidity and mortality.

In addition to the value to the literature on climate change, the present study has limitations mainly because of selecting one district and towns purposively as the study area. The findings of the study cannot be generalized to other cities with diverse nature of urban landscape characteristics. Adaptation to heat waves and its impact on human morbidity can best be

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explained by using information collected overtime. However, the present study used cross-sectional data. Future research is warranted to focus on cities with diverse urban landscape characteristics, infrastructure and weather using data collected overtime. Another future research area is to consider rural areas as well as the present study did not focus on the rural community with little access to information and health facilities. However, the present study provides useful insights on adaptation to heat waves and the consequent impact on human health.

6. Conclusions

Heat waves commonly happen during the summer in Pakistan, causing number of morbidity and mortality. Adaptation is considered important to prevent the adverse effects of heat waves. The findings of this study suggested that a considerable percentage of the respondents not following the media news relating to preventive measures during heat waves provides insight for policy concern. This implies that the awareness campaign should be designed for the urban and peri-urban households. Information on the heat waves provided by the print and electronic media may not be received by the population at large. Training and awareness programs at school and college levels are viable options. Similarly, health workers and staff of extension services could be trained in the specially arranged workshops. These are helpful in disseminating information because information would be provided efficiently in person and it would be more effective.

We also found that adaptation to heat waves significantly contributed in reducing morbidity relating to heat waves. The urban/ peri-urban background of the respondent, family size, income level of the respondents, and number of males in the house were all significant factors affecting heat relating morbidity. Factors promoting adaptation of the household may be facilitated through increasing adaptive capacity. Adaptation practices are costly, and high poverty due to low income in Pakistan necessitates provision of energy efficient appliances at low cost.

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Programs and policies focusing on population behavioral change should consider financial capacity of different segment of the target population. Population with low income and high risk of vulnerability requires special attention of the policymakers.

One other aspect is that the electricity demand rises during heat waves as a result of air conditioning. Electricity shortage affects substantially the low income population as they are not able to afford other means of energy sources compared to the high income population. In order to avoid an increase in energy demand particularly during heat waves, renewable energy sources such as solar and wind energy may be popularized through subsidy programs among the masses. Targeted subsidy program and policy would be more effective policy option for motivating the low income population to adopt renewable energy sources.

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References

Abrahamson, V., Wolf, J., Lorenzoni, I., Fenn, B., Kovats, S.,Wilkinson, P., Adger, W.N., Raine, R. (2008). Perceptions of heat wave risks to health: Interview-based study of older people in London and Norwich, UK. J Public Health-UK 31:119–126.

Akompab, D.A., Bi, P., Williams, S., Grant, J., Walker, I.A., Augoustinos, M. (2013). Awareness of and attitudes towards heat waves within the context of climate change among a cohort of residents in Adelaide, Australia. Int J Env Res Pub He 10:1–17.

Algina, J., Olejnik, S. (2003) Sample size tables for correlation analysis with applications in partial correlation and multiple regression analysis. Multivar Behav Res 38:309–323

ACCEPTED MANUSCRIPT

Ariane, A.P., Labrèche, Smargiassi, A., Duguay, P., Busque, M., et al. (2013), Studies and research projects impacts of climate change on occupational health and safety special projects p: 775

Bakhsh, K., Rauf, S., Abbas, A. (2016). Knowledge, perception and socioeconomic vulnerability of urban and peri-urban households to heat waves in Pakistan. Nautiyal S. et al. (eds.),Climate Change Challenge (3C) and Social-Economic-Ecological Interface-Building, Environmental Science, Springer International Publishing Switzerland.

Barnett, A.G., Tong, S., Clements, A.C. (2010). What measure of temperature is the best predictor of mortality? Environ Res 110:604–611

Basu, R, (2009), High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008. Environ Health-Glob 8:40.

Basu, R. and Samet, J.M. (2002). Relation between elevated ambient temperature and mortality: A review of the epidemiological evidence. Epidemiol Rev, 24:190–202

Bi, L., Ding, G., Gu, S., Bi, P., Su, B., Qin, D., Xu, G., Liu, Q. (2014). The effects of summer temperature and heat waves on heat-related illness in a coastal city of China, 2011–2013. Environ Res 132:212–219.

Bobb, J.F., Dominici, F., Peng, R.D. (2011). A Bayesian model averaging approach for estimating the relative risk of mortality associated with heat waves in 105 U.S. cities. Biometrics 67:1605–1616

Bouchama, A., Dehbi, M., Mohamed, G., Matthies, F., Shoukri, M., Menne, B. (2007). Prognostic factors in heat wave related deaths: A meta-analysis. Arch Intern Med 167:2170–2176.

ACCEPTED MANUSCRIPT

Brewer, N.T., Weinstein, N.D., Cuite, C.L., Herrington, J.E. (2004). Risk perceptions and their relation to risk behavior. Ann Behav Med 27:125–130.

Das, S. and Smith, S.C. (2012). Awareness as an adaptation strategy for reducing mortality from heat waves: evidence from a disaster risk management program in India. Clim Change Econ 3:1250010

Das, S. (2016). Television is more effective in bringing behavioral change: Evidence from heat-wave awareness campaign in India. World Development 88:107-121.

Deressa, T.T., Hassan, R.M., Ringler, C. (2011). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. J Agr Sci 149:23–31.

Deryugina, T. (2013). How do people update? The effect of local weather fluctuations on beliefs about global warming. Climatic Change 118:397–416.

Dholakia, H., Amit, G. (2014). A tale of five cities: Heat waves, cold spells and mortality risk in urban India. Indian Institute of Management, Ahmedabad. pp: 1-16

Dole, R., Hoerling, M., Perlwitz, J., Eischeid, J., Pegion, P., Zhang, T., Quan, X.W., Xu, T., Murray, D. (2011). Was there a basis for anticipating the 2010 Russian heat wave? Geophys Res Lett 38:1–5.

Falco, S.D., Veronesi, M., Yesuf, M. (2011). Does adaptation to climate change provide food security? A micro perspective from Ethiopia. Am J Agr Econ 93: 829–846.

Gallagher, J. (2014). Learning about an infrequent event: Evidence from flood insurance take-up in the U.S. American Economic Journal: Applied Economics 6:206–233.

Glum, J. (2015). Pakistan heat wave 2015: death toll exceeds 1,200 as Karachi struggles with continued extreme weather during Ramadan. Int Busin Times dated 27-06-2015.

ACCEPTED MANUSCRIPT

Available online at http://www.ibtimes.com/pakistan-heat-wave-2015-death-toll-exceeds-1200-karachi-struggles-continued-extreme-1986866

GOP. (2016). Pakistan Economics Survey 2015-2016. Ministry of Finance, Government of Pakistan, Islamabad

Green, S.B. (1991). How many subjects does it take to do a regression analysis. Multivar Behav Res 26:499–510

Grothmann, T., Patt, A. (2005). Adaptive capacity and human cognition: The process of individual adaptation to climate change. Global Environ Chang 15:199–213.

Guirguis, K., Gershunov, A., Tardy, A. and Basu, R. (2014). The impact of recent heat waves on human health in California. J Applied Met Climatology 53:3-19

Haider, K.W., Rasul, G., Afzaal, M. (2008). A study on tropical cyclones of the Arabian Sea in June 2007 and their connection with sea surface temperature. Pak J Meteorol 4:37–48

Hansen, A., Bi, P., Nitschke, M., Pisaniello, D., Newbury, J., Kitson, A. (2011). Perceptions of heat-susceptibility in older persons: Barriers to adaptation. Int J Env Res Pub He 8:4714–4728

Hansen, A., Bi, P., Nitschke, M., Ryan, P., Pisaniello, D., Tucker, G. (2008). The effect of heat waves on mental health in a temperate Australian City. Environ Health Perspect 116:1369–1375.

Hassan, R., Nhemachena, C. (2008). Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. Afr J Agr R Econ 2:83–104.

IPCC. (2012). Managing the risks of extreme events and disasters to advance climate change adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)].

ACCEPTED MANUSCRIPT

A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA.

Jaswal, A.K., Rao, P. C. S. and Singh, V. (2015). Climatology and trends of summer high temperature days in India during 1969–2013.Journal of Earth System Science, 124:1–15

Kaleon, K.P., Acharya, S.K., Bera, S. (2013). People's perception on climate change in a typical hill ecosystem of Sikkim. Research J Agri Sci 4:237–240

Kikon, N., Singh, P., Singh, S.K., Vyas, A. (2016). Assessment of Urban Heat Islands (UHI) of Noida City, India using multi-temporal satellite data. Sustainable Cities and Society http://dx.doi.org/10.1016/j.scs.2016.01.005

Kolachi, H.B.A., Kazi, A., Almani, S. and Shah, A.H. (2008). Heat stroke victims in Sukkur city of Sindh – Pakistan. Biomedica 24:67–70

Kosatsky, T., Dufresne, J., Richard, L., Renouf, A., Giannetti, N., Bourbeau, J., Julien, M., Braidy, J., Sauve, C. (2009). Heat awareness and response among Montreal residents with chronic cardiac and pulmonary disease. Can J Publ Health 100:237–240

Kovats, R.S., Hajat, S. (2008) Heat stress and public health: a critical review. Annu Rev Publ Health 29:1–15

Liu, T., Xu, Y.J., Zhang, Y.H., Yan, Q.H., Song, X.L., Xie, H.Y. et al. (2013). Associations between risk perception, spontaneous adaptation behavior to heat waves and heatstroke in Guangdong Province, China. BMC Public Health 13:1–14

Lowe, D., Ebi, K.L. and Forsberg, B. (2011). Heatwave early warning systems and adaptation advice to reduce human health consequences of heatwaves. Int J Environ Res Public Health 8:4623-4648

ACCEPTED MANUSCRIPT

Lu, R.L. and Chen, R.D. (2016). A review of recent studies on extreme heat in China. Atmos. Ocean. Sci Lett 9:114–121

Maida, Z. and Rasul, G. (2011). Changing trends of thermal extremes in Pakistan. Clim Change http://dx.doi.org/10.1007/s10584-011-0390-4

Martiello, M.A. and Giacchi, M.V. (2010). Review article: High temperatures and health outcomes: A review of the literature. Scand J Public Health 38:826–837

Matthies, F. and Menne, B. (2009). Prevention and management of health hazards related to heat waves. Int J Circumpol Heal 68:8–22

Mehmood, K., Arshad, M., Ali, S., Qayyum, M. and Ali, G.M. (2016). Comparative study of tissue culture response of some selected basmati rice cultivars of Pakistan. J Agric Rural Dev 1:30–38

Mirza, M.M.Q. (2003). Climate change and extreme weather events: can developing countries adapt? Climate Policy 3:233-248

Mueller, V., Gray, C. and Kosec, K. (2014). Heat stress increases long-term human migration in rural Pakistan. Nature Climate Change 4:182–185

Nasim, W., Amin, A., Fahad, S., Awais, M., Khan, N., Mubeen, M., Wahid, A., Turan, V., Rehman, M.H., Ihsan, M.Z., Ahmad, S., Hussain, S., Mian, I.A., Khan, B. and Jamal, Y. (2018). Future risk assessment by estimating historical heat wave trends with projected heat accumulation using SimCLIM climate model in Pakistan. Atmospheric Research 205:118-133

Neumayer, E., Plumper, T. and Barthel F. (2014). The political economy of natural disaster damage. Global Environmental Change 24:8–19

ACCEPTED MANUSCRIPT

Nitschke, M., Tucker, G.R. and Bi, P. (2007). Morbidity and mortality during heat waves in metropolitan Adelaide. Med J Australia 187:662–665

Osgood, D.W. (2000). Poisson-based regression analysis of aggregate crime rates. J Quant Criminol 16:21–43.

Page, L.A., Hajat, S. and Kovats, R.S. (2007). Relationship between daily suicide counts and temperature in England and Wales. Br J Psychiatry 191:106–112

Panda, D.K., Mishra, A., Kumar, A., Mandal, K.G., Thakur, A. K. and Srivastava, R.C. (2014). Spatiotemporal patterns in the mean and extreme temperature indices of India, 1971–2005. Int J Climatology 34:3585–3603

PBS. (2018). Pakistan Bureau of Statistics. Government of Pakistan, Islamabad

Piza, E.L. (2012). Using poisson and negative binomial regression models to measure the influence of risk on crime incident counts. Rutgers Center on Public Security.

Rasul, G., Chaudhry, Q.Z., Sixiong, Z., Qingcum, Z., Linlin, Q.I. and Gaoying, Z. (2005). A diagnostic study of heavy rainfall in Karachi Due to merging of a mesoscale low and a diffused tropical depression during south Asian summer monsoon. Adv Atmos Sci 22:375–391

Rauf, S., Bakhsh, K., Abbas, A., Hassan, S., Ali, A. and Kächele, H. (2017). How hard they hit? Perception, adaptation and public health implications of heat waves in urban and peri-urban Pakistan. Environ Sci Pollut R DOI 10.1007/s11356-017-8756–4

Reischl, C., Rauter, R. and Posch, A. (2016). Urban vulnerability and adaptation to heatwaves: a case study of Graz (Austria). Climate Policy DOI:10.1080/14693062.2016.1227953

ACCEPTED MANUSCRIPT

Robine, J.M., Cheung, S.L.K., Roy, S.L., Oyen, H.V., Griffiths, Michel, J.P. and Herrmann, F.R. (2008). Death toll exceeded 70,000 in Europe during the summer of 2003. CR Biol 331:171–178

Saeed, F. and Suleri, A.Q. (2015). Future heat waves in Pakistan under IPCC's climate change scenario. Sustainable Development Policy Institute (SDPI) Policy Brief 46, Islamabad, Pakistan

Sheikh, S. and Tunio, S. (2013). Pakistan wilts under record heat wave. Thomson Reuters Foundation. Available:http://streettimes.com.pk/pakistan-wilts-under-record-heat-wave/.

Sherwood, S.C. and Huber, M. (2010). An adaptability limit to climate change due to heat stress. P Natl Acad Sci USA 107:9552–9555

Son, J.Y., Lee, J.T., Anderson, G.B. and Bell, M.L. (2012). The impact of heat waves on mortality in seven major cities in Korea. Environ Health Persp 120:566–571

Strömberg, D. (2007). Natural disasters, economic development, and humanitarian aid. J Econ Persp 21:199-222.

Umoh, V., Peters, E., Erhabor, G., Ekpe, E. and Ibok, A. (2013). Indoor air pollution and respiratory symptoms among fishermen in the Niger delta of Nigeria. Afr J Respir Med 9: 1-5.

Vaneckova, P., Neville, G., Tippett, V., Aitken, P., Fitzgerald, G. and Tong, S. (2011). Do biometeorological indices improve modeling outcomes of heat-related mortality? J Appl Meteorol 50:1165–1176

WMO. (2013). The global climate 2001–2010. In: A decade of climate extremes. World Meteorological Organization. WMO-No. 1103, Switzerland (119pp.)

ACCEPTED MANUSCRIPT

Woodruff, R.E., McMichael, T., Butler, C. and Hales, S. (2006). Action on climate change: the health risks of procrastinating. Aust NZ J Public Health 30:567–571

Zahid, M. and Rasul, G. (2010). Rise in summer heat index over Pakistan. Pak J Meteor 6:85–96

Zhi-hui, H., Tao, L.,Yan-jun, X., Xiu-ling, S., Qing-hua, Y., Hui-yan, X., Shao-en, Z., Wen-jun, M. (2013). Investigation on adaptation behaviors to heat wave and its relative factors in residents of Guangdong Province. S China J Prev Med 39:12–17

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Table 1 Summary statistics of the variables

Variables	**Urban**	**Peri-urban**
Adaptation to heat waves (score)	27.08 (3.46)	26.31 (3.40)
Background of the respondent (%)	60	40**
Age (years)	35.88 (13.97)	36.69 (12.35)
Family size (No.)	6.19 (3.03)	6.64 (2.82)
Schooling year of the head of household	13.17 (4.09)	9.11 (5.39)
Income level (%)		
Low	7	24***
Middle	25	44***
High	67	33***
Males in households (No.)	67	48**
No. of observations	150	101

Figures in parentheses are standard deviation

*** p<0.01, ** p<0.05, * p<0.1

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Table 2 Response percentage to the statements on adaptation to heat waves

Statements	Urban			Peri-urban		
	Never	Sometimes	Always	Never	Sometimes	Always
Drink plenty of water to be hydrated	-	10.67	89.33	1.98	6.93	91.09
Drink more milk, juices	6.67	16.00	77.33	4.95	19.80	75.25
Wear dark coloured clothes when going outside	66.67	19.33	14.00	43.56	29.70	26.73
Listen to daily weather forecast	19.33	38.67	42.00	33.66	31.68	34.65
Change working time during heat waves	22.00	32.00	46.00	24.75	28.71	46.53
Go for a swim/canal to cool down	72.00	19.33	8.67	55.45	31.68	12.87
Seek protection of shady areas when out of home	2.67	14.00	83.33	5.94	36.63	57.43
Go to shopping or meeting relatives in the peak hours of heat waves	20.00	26.67	63.33	16.83	38.61	44.55
Use an umbrella/cloth/cap when walking outside	40.00	24.00	36.00	36.63	21.78	41.58
Use Sun-Block/sunglasses	36.00	21.33	42.67	59.41	22.77	17.82
Increase the number of baths	3.33	16.67	80.00	3.96	11.88	84.16
Wear full sleeves	19.33	20.00	60.67	13.86	23.76	62.38

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Use green sheets/chicks in house	37.33	20.67	42.00	43.57	27.72	28.71
Increase air-conditioner use	1.49	61.19	37.31	14.29	47.62	38.10

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Table 3 Impact intensity and adaptation to heat waves

Particulars	**Urban**		**Peri-urban**	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Experienced illness related to heat waves	61	40.7	36	35.6*
Hospitalized due to heat waves related illness	15	10.0	7	6.9
Adaptation among the patients suffered from heat waves				
Good adapters	26	42.6	13	36.1*
Poor adaptors	35	57.4	23	63.9*

* $p<0.1$

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Table 4 Estimates of Poisson regression model

Variables	Coefficient (Std. Error)	IRR (Std. Error)
Adaptation to heat waves	-0.154*** (0.022)	0.857*** (0.019)
Background (Urban=1)	0.264* (0.156)	1.302* (0.204)
Family size	0.136*** (0.039)	1.146*** (0.044)
Schooling years of the head	-0.013 (0.016)	0.987 (0.015)
Level of income (1=High)	-0.184* (0.112)	0.831* (0.092)
No. of males	-0.107* (0.066)	0.898* (0.059)
Constant	3.59*** (0.594)	

Standard errors in parentheses. IRR = Incident Rate Ratio

*** p<0.01, ** p<0.05, * p<0.1

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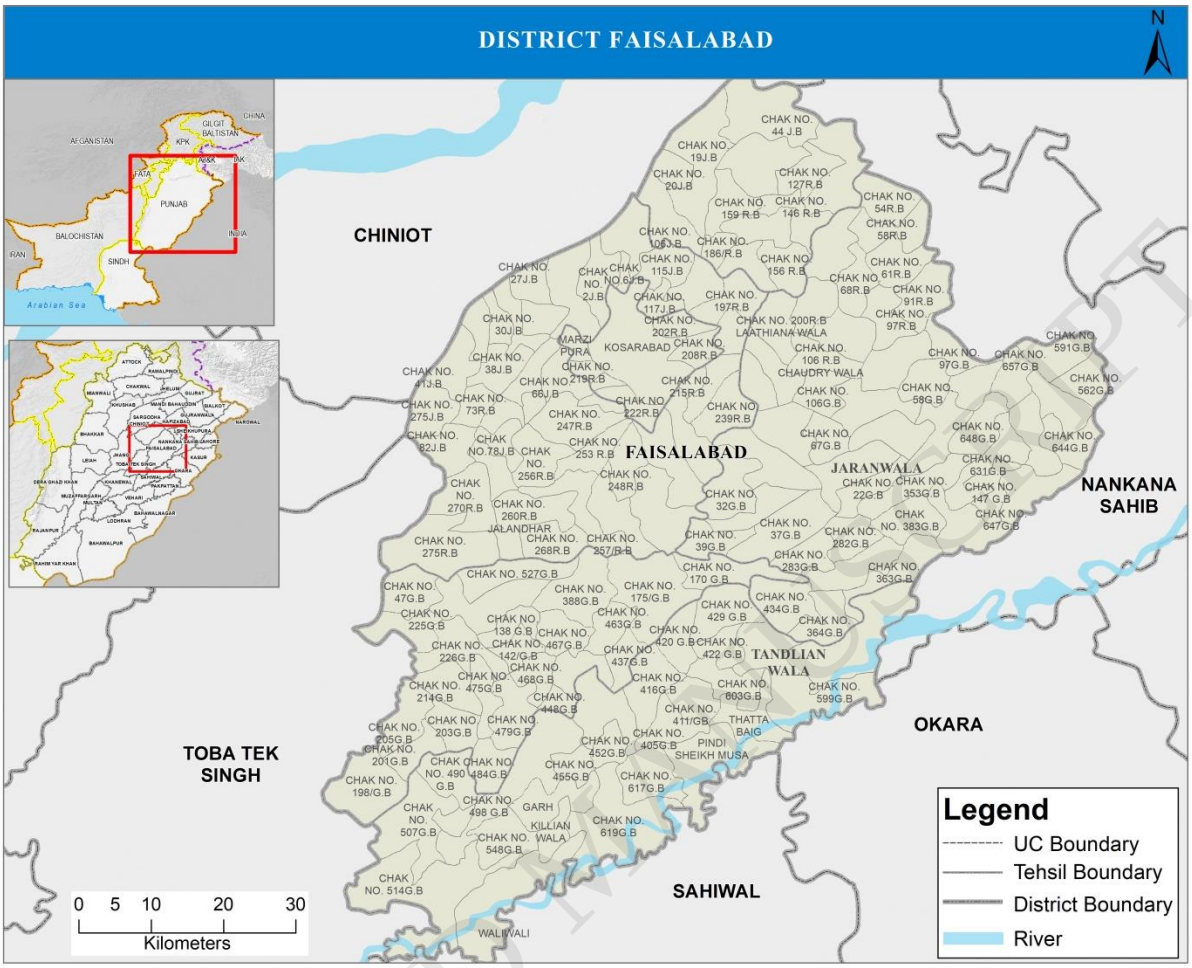

Figure 1. Map of Faisalabad district of Pakistani Punjab

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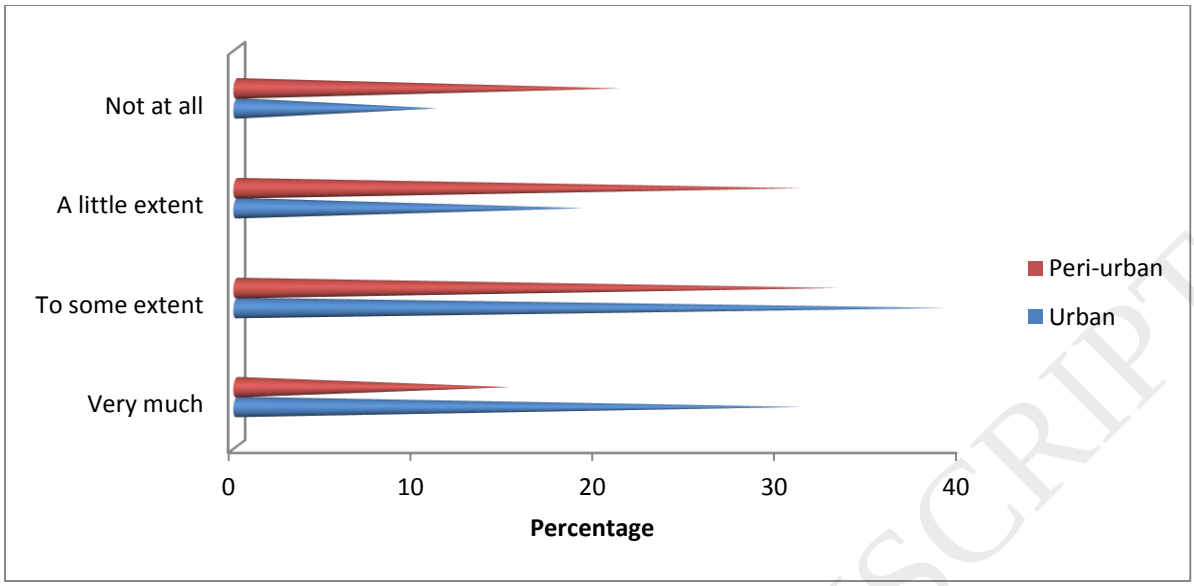

Figure 2 Responses on the extent of following the information on heat waves

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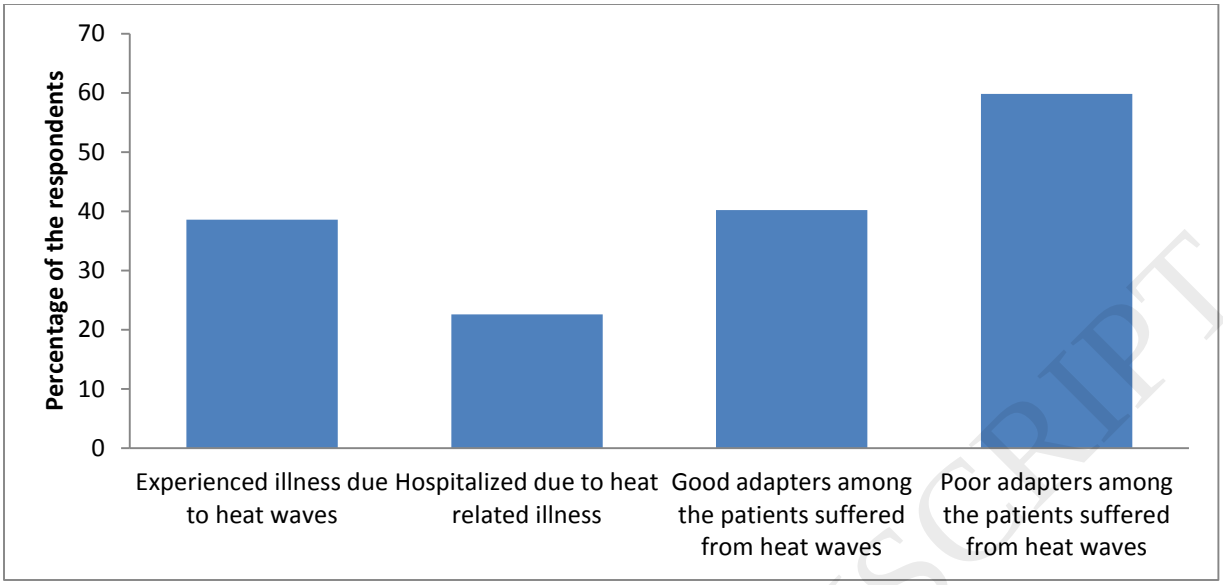

Figure 3 Impact intensity and adaptation to heat waves in the study area

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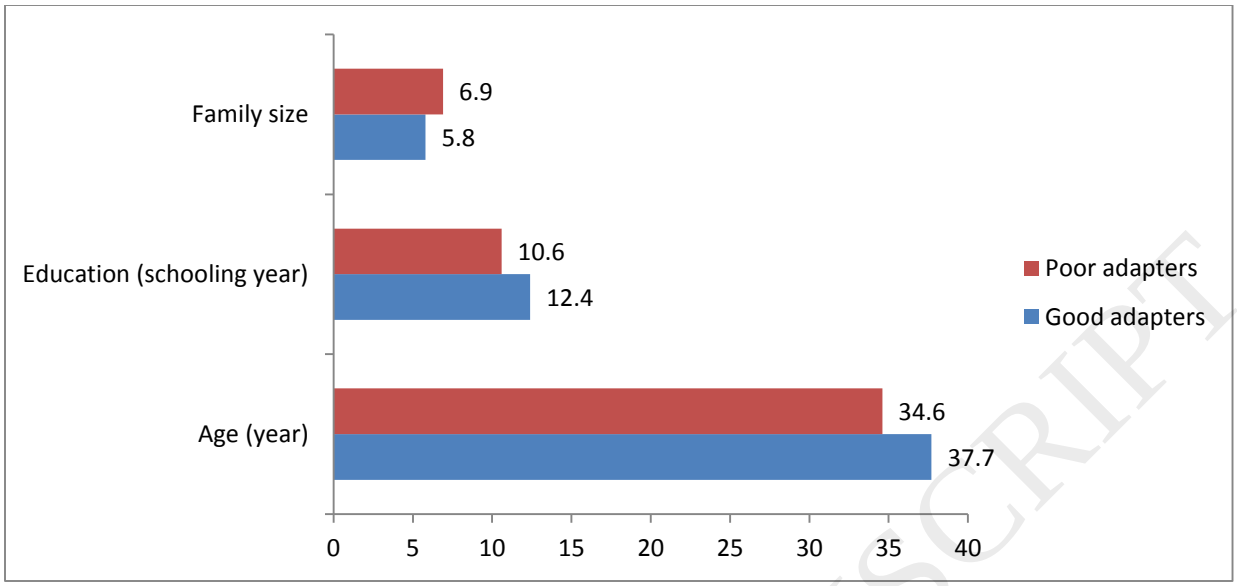

Figure 4 Relationship between adaptation and sociodemographic characteristics

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