Weather and extreme heat in association to mental disorders

The case of Hanoi, Vietnam

Phan Minh Trang
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"The best people are like water, which benefits all things and does not compete with them. It stays in lowly places that others reject. This is why it is so similar to the Way"  Lao-Tzu
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Abstract

**Background:** Vietnam suffers consequences of global warming. There is limited data of the relationship between weather, extreme heat and potential mental health problems. It is therefore crucial to study heat-related mental illnesses and to establish good solutions with relevant adaptations to global warming. The adaptation measures should give attention to people that live in areas facing annual extreme weather, and protecting health in general and more specifically mental health of citizens. The study aimed to examine relationships between weather patterns, extreme heat or heatwaves, and mental disorders, and to investigate factors contributing to increased vulnerability and susceptibility.

**Methods:** The thesis includes a systematic review and a hospital-based study using data from the Hanoi Mental Hospital for five years (2008 – 2012), with mental disorders diagnosed by ICD10 (F00-99) to estimate the effects of weather variation, seasonality, increased temperatures, and heatwaves on hospital admissions for depression and other mental disorders. A negative binomial regression model accounting for yearly study period, time trends, and day of the week was used to analyze the relationship between seasonality, heatwaves, and monthly and daily mental disorder hospitalizations.

**Results:** Our findings showed (i) a general tendency for more admissions between May and December, with a seasonal bi-annual high between May-June and November-December, and elevated ambient temperature was significantly related to increasing admissions for depressive disorders; (ii) the number of hospital cases for mental disorders increased in the summer season especially in June, and two percent of cases emerged during elevated temperature of one degree Celsius; and (iii) when compared with non-heatwave periods, heatwaves amounted to increasing risks for admission for the whole group of mental disorders (F00-79), and admissions for mental disorders among residents in rural communities and in the elderly population increased significantly during heatwaves.

**Conclusion:** There were associations between hospital admissions for depression and other mental disorders and seasonality, weather patterns, elevated temperatures, and heatwaves. The associations grew stronger with the length of the heatwaves and particularly the elderly appeared more sensitive to seasonality, hot weather and heatwaves.

**Key words:** Depressive disorders, mental disorders, weather patterns, elevated temperature, and heatwaves.
Prologue

Like other poor nations, Vietnam has focused more attention on physical health problems such as non-communicable and communicable diseases, whereas mental disorders have received less attention due to insufficient knowledge, the poor health care system, or to social discrimination. I am a Vietnamese physician, working in the area of environmental and occupational health. Like many other medical doctors, I have rarely worked on mental health problems. Climate change has brought challenges to the world, and my country located in a subtropical region suffers every year, and mental health problems are an additional increasing challenge. Thus, I have a desire to examine the impact of climate change, especially extreme heat and heatwaves on mental disorders, and in setting up good strategies for preventing mental health problems. It is of course difficult to avoid the natural disaster occurrence, but we can prevent heat-related mental illnesses particularly in poor people who need real help and protection. This was one of the reasons I joined a research group at Hanoi medical university in 2012. A goal is to better understand mental health problems in my country in relation to environmental factors and effects as well as to personal characters, social determinants, culture, gender, marriage status, and socioeconomic factors. The poor and more vulnerable population could have improved opportunities and capacities to overcome physical health problems if they had a healthier mental life.

During the time studying at Umeå University I have had more time to obtain information related to mental health problems and I have enhanced my knowledge regarding mental health problems in Vietnam. This may be of help in the future to set up good preparedness, preventive and intervention programs for mental health problems in Vietnam where human wellbeing and mental health have not received proper concern.

So many things need to be done in developing nations like Vietnam. The country is located in a subtropical region where millions of people experience annually consequences of climate change such as tropical storms, severe floods, and heatwaves. Those who suffer most are the poor and extremely poor, especially in the middle of Vietnam. Demographic transition to big cities among the population that suffer from climate change consequences has increased recently. This will create the burden of socioeconomic growth and security in cities such as Hanoi and Ho Chi Minh City. Both physical and mental health problems have been a burden for city populations but also for migrants. One of my biggest concerns is how to improve mental public health in my city but also in Vietnam as a whole.
**Abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tr>
<td>WHO</td>
<td>World Health Organization</td>
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<td>ICD 9-10</td>
<td>International Classification Disease 9 or 10</td>
</tr>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>5-HT</td>
<td>5-hydroxytryptamine</td>
</tr>
<tr>
<td>5-HT₁₆ receptor</td>
<td>A subtype of 5-hydroxytryptamine receptor</td>
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<tr>
<td>GABA</td>
<td>Gamma-Aminobutyric acid</td>
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<tr>
<td>YLDs</td>
<td>Years Lived with Disability</td>
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<td>DALYs</td>
<td>Disability Adjusted Life Years</td>
</tr>
<tr>
<td>PTSD</td>
<td>Posttraumatic stress disorder</td>
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<tr>
<td>LMICs</td>
<td>Low-and-middle income countries</td>
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<tr>
<td>RRs</td>
<td>Relative risks</td>
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<td>CIs</td>
<td>Confidence intervals</td>
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Glossary of terms

1. **Weather and heatwaves**

   “*Weather* is the condition of the atmosphere at a particular place over a short period of time. While *climate* refers to the weather pattern of a place over a long period, long enough to yield meaningful averages.” (1)

   “*A heatwave* is a prolonged period of excessively hot weather, which may be accompanied by high humidity. A heatwave is measured relative to the usual weather in the area and relative to normal temperatures for the season. Temperatures that people from a hotter climate consider normal can be termed a heatwave in a cooler area if they are outside the normal climate pattern for that area. The term is applied both to routine weather variations and to extraordinary spells of heat which may occur only once a century.” (1)

2. **Mental health and mental disorders**

   “*Mental health* is defined as a state of well-being in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community.” (2)

   “*Mental disorders* (F00-99) comprise a broad range of problems, with different symptoms. However, they are generally characterized by some combination of abnormal thoughts, emotions, behavior and relationships with others”. Most of these disorders can be successfully treated.” (2)
Original Papers

The thesis is based on the following papers:

I- Phan Minh Trang, Barbara Schumann, Joacim Rocklöv, Julia Schröders and Maria Nilsson. The Influence of Heatwaves on Mental and Behavioral Disorders: A systematic Review and Meta-analysis (draft).


Introduction and Background

Climate change is a global challenge through its effects on human health and well-being due to the exposure to weather variations and extreme weather such as heatwaves, floods, storm-surges, drought that bring about increased morbidity and mortality worldwide (3-5).

Direct effects of climate change on human health occur by changing temperatures and precipitation; these increase the occurrence of heatwaves, droughts, storms, floods (6). Indirect impacts occur by ecological disruptions and social response to climate change (6). Thus, health problems, both infectious and non-infectious diseases, due to climate change effects have emerged globally, and special regions like the Asian area are impacted much more (6, 7). Recently, many studies have been conducted throughout the world on mortality and morbidity related to climate change. The impacts on physical health such as cardiovascular, respiratory, kidney, and infectious diseases were reported much more than that on psychiatric health problems despite that mental health problems are increasing in both developed and developing nations worldwide (6, 8).

Benefits from economic growth and advanced social development will contribute to a reduction in but will not eliminate the impacts on human health especially in the poorest and least healthy groups (6).

One serious consequence owing to climate change is a rising temperature (9). The higher temperatures that occur increases the occurrence of heatwave events and severe droughts (10). This has caused health problems including physical and mental health in which the number of cases for mental health problems such as depressive disorders, drug abuse, alcohol abuse, dementia, and anxiety may increase during extreme heat events (8).

1. Temperature variation globally

An increase in the Earth’s surface temperature takes place much more rapidly today as one serious consequence of global warming (10). According to the Intergovernmental Panel on Climate Change (IPCC), the average surface temperature has risen by approximately 0.6°C since the mid-19th century and is forecasted to increase further by 1.1°C to 6.4°C by the end of the 21st century (3, 11) (Fig 1). Thus, an increase in the surface temperature may bring about heatwaves more often and they last longer in many regions worldwide (6, 10).
In the Asian region rising temperatures and warming trends have increased over the past century, and this will continue into the new millennium (12). The extreme weather events will have an impact on human health, security, livelihoods and poverty with varying magnitude and pathways (7). There is an estimate of increased mortality and morbidity among vulnerable populations in this region due to more frequent and intense heatwaves (10, 12). More frequent flooding and droughts in some Asian areas will increase rural poverty due to negative impacts on the rice crop and rises in food prices and living costs (7, 13). Moreover, rapid urbanization,
industrialization, and economic growth with the increased emissions of carbon dioxide and greenhouse gases will contribute to consequences of global warming in this region (7). According to the World Bank, climate change has affected the sustainable development capabilities of most Asian developing countries, thereby aggravating damage of natural resources and environment (13).

2. The burden of mental health over the world

In parallel with an increase in consequences of climate change, the disease burden of mental health problems has become a big concern globally and in low and middle income countries (LMICs) like Vietnam.

Mental health problems have become a burden of disease over the world in both high and low and middle income countries (14, 15). According to a WHO’s report from 2004, there was an estimate of 13% of the global disease burden for mental health problems (15). Almost all psychiatric problems were chronic diseases spending years with disability accounted for 25.3% in developed nations and 33.5% in developing nations of all years lived with disability (15).

A systematic review of international studies (1980 – 2010) in 2010 showed that there were 10.4% of global disability-adjusted life years (DALYs) and 28.5% of global years lived with disability (YLDs) caused by mental, neurological and substance use disorders (16). Mental disorders were estimated to have the highest proportion of DALYs (56.7%) compared with neurological disorders (28.6%) and substance consumption disorders (14.7%) (16). Depressive disorders, anxiety disorders, drug use disorders, alcohol abuse, and schizophrenia contributed 40.5%, 14.6%, 10.9%, 9.6%, and 7.4% of DALYs, respectively (16, 17). Mental, neurological, and substance use disorders have increased in both high-income nations and LMICs and have accounted for nine out of the 20 leading causes of YLDs (18). The burden of mental and substance use disorders increased by 37.6% during twenty years (1990-2010) for which growth of the aging population accounted for the highest risk of mental disorders (19, 20). Substance use disorders were shown as a combined estimate involving harmful use and dependence of opioids and cocaine (16, 18). Disability or morbidity due to mental, neurological and substance use disorders can develop from the genetic, biological and psychological conditions of individuals as well as from adverse social conditions and environmental factors (6, 16).

Globally, depressive disorders prevalent in 350 million people have become the most disabling disorder calculated in YLDs, and is the fourth
leading cause of the overall disease burden estimated in DALYs by all ages and both sexes (21). In addition, major depressive disorder will become the largest cause triggering disability worldwide in 2030 according to a recent WHO report (21).

People with dementia, epilepsy and schizophrenia accounted, respectively, for 35.6 million, 50 million and 24 million people worldwide (15). Schizophrenia is a severe mental disorder, that commonly impacts studies and the work situation for those suffering from the disease (15, 18). As a chronic and progressive nature deterioration in cognitive function, dementia has had an increased trend both in developed and developing countries (15). According to the 2016 report on mental health problems, there was a worldwide increase in the estimate for deaths due to Alzheimer’s disease and other dementias by almost 40% from 2005 to 2015 (22). In addition, mental health problem including depression, anxiety disorders, schizophrenia, bipolar disorder, and alcohol and drug use disorders may contribute to most deaths due to self-harm (22).

Autism is an intellectual disability that contributes to many cases of mental disorders; it is in need of more demand of the health services (14, 20).

Following WHO’s report, on a global level three quarters of the people with depression and anxiety were estimated to be in LMICs (15, 23, 24). However, many LMICs currently spend less than 2% of their limited health budget on treatment and prevention of mental disorders, despite mental health problems having an increased trend as a burden of public health and economic development (14).

It is difficult for most persons with mental ill-health to access essential care services for mental health in LMICs, particularly for poor people paying for care out-of-pockets (25). In community based settings of LMICs, an integrated package of cost-effective care and prevention could be supported for 3–4 USD per capita (20). This was not easy for poor populations and governments (14, 15). Thus, integration of mental health care into publicly-funded primary care and task-sharing with non-specialist health-care providers may be more appropriate for access to health care services (25). Moreover, mental patients and their families have been commonly subjected to stigma, discrimination and victimization in LMICs (20, 26). Hopefully, there will be also well-formulated and properly enforced policies and laws oriented to human rights to prevent abuse and protect rights.

In LMICs, despite the high risk of mental health problems, there have been low government health expenditures on mental health care service (14).
In addition, “catastrophic” out-of-pocket expenditure on health services may be also a major difficulty among populations at risk, especially among people suffering more from environmental impacts (14, 24). An analysis for India showed that half of the out-of-pocket expenditures made by households for psychiatric disorders came from loans, and a further 40% from household income or savings (27). Another study in the state of Goa in India indicated that an estimate of 15% of women with a common mental disorder spent over 10% of the household income on health-related expenditures (20, 27).

According to the World Economic Forum, an amount of 16 trillion USD over the next 20 years will be estimated for cumulative global impact of mental disorders in terms of lost economic output (12). This may lead to a highly significant concern not only for public health but also for economic growth and societal welfare (26).

Thus, the burden of mental health problems is one of great concern worldwide particularly for LMICs. Not only are preventing and treating mental, neurological and substance use disorders very important, but also improving knowledge, attitude, and practice related to mental disorder prevention is quite necessary, especially among poor countries.

Although there have recently been some international studies on climate change in association to morbidity and to mental health in particular, the research on heat-related mental illness has been limited (6, 8). The question arises that when more heatwave events appear, would mental health problems develop much more often especially in nations with low-and-middle incomes in Asian regions like Vietnam (6, 15).

3. The research on climate change in association to mental health and well-being

The interest for climate change-related potential impacts on human health and well-being has increased. However, potential effects of psychological and social problems have received less attention because most psychosocial impacts are of a gradual and cumulative nature (8). Psychological problems in association with global climate change may be also difficult to identify (28). The relationship between climate change, weather variation and mental health issues have started to get attention in recent years by scientists and psychologists (5, 28-30).

Disaster-related psychiatric trauma includes severe anxiety reactions such as post-traumatic stress, and longer-term impacts such as generalized anxiety, depression, aggression and complex psychopathology (6, 31). For
Children, short-term responses to disaster may include developmental regression, clinging behavior, aggressiveness, inattentiveness, bed-wetting (in young children), somatic complaints, irritability, social withdrawal, and frequent crying (32). Moreover, a higher risk of PTSD may lead to cause reproductive, metabolic, and immunological problems (8).

Extreme weather conditions may have indirect effects on mental disorders through pathways of the impact on agricultural productivity, fishing, forestry, and other economic activities (8). “Solastalgia” was known as effects of extreme weather events on mental health via the risk/disadvantage cycle where there may be a distressing sense of loss (6, 8), for example, people suffered when their land was damaged and they lost amenity and opportunity (8, 33).

Moreover, extreme climate events have also affected all levels from an individual to a community perspective, including community systems of physical and social infrastructure (8). The events may also influence the region, state, and country in which poorer communities will tend to be more difficult to save and recover after extreme weather occurrence (6, 8). This may influence partly on mental health status of individuals and community (8). Climate change could occur in developing countries that already have had a weak health infrastructure and a weak system for mental health services (8). This may increase the risk for climate change-related mental disorders especially in vulnerable populations such as children and elderly (8, 34). For example, LMICs had 0.05 psychiatrists and 0.16 psychiatric nurses per 100,000 people, while in high-income countries these were more than 200 times more common (15, 20). According to the WHO 76–85% of serious mental health cases in less-developed countries had received no treatment in the previous 12 months (15). A big problem has arisen for mental health care systems in low-resource settings or poor countries with high disease burden and low service levels for mental health (15, 20). Furthermore, mental health problems related to climate change may lead to an increase of adverse impacts on humanitarian crises including poverty, low education, political insecurity, and social exclusion (15, 35). Further vulnerability such as poor physical health and lower economic productivity may be caused by climate change-associated mental illness (8, 15).

Although the research on addressing the psychological and mental health due to consequences of climate change has been modest, it has been particularly relevant to the awareness of populations for storms, floods, droughts and mental health problems due to the threads (8, 36, 37). However, further studies as well as perspectives from health and clinical psychology, psychiatry, disaster-related mental health, multidisciplinary risk
communication and response, and environmental phenomenology will be conducted in the future (8, 29, 38).

4. The research on the relationship between seasonality and mental health and well-being

The relationship between mood, behavior disorders and seasons has a long history (39, 40). In ancient time, researchers reported variations of illnesses with the seasons mentioning the relationships between seasonal weather conditions, manias and melancholies (41). In modern time, seasonal variations in mental disorders that include suicide, perception of anti-depressive medication, administration of electroconvulsive therapy and admissions for mood disorders have been studied (39). According to researchers, seasonal affective disorder sufferers have the onset of symptoms between September and December in the northern hemisphere, and the winter or seasonality-related syndromes developed in the spring and summer among population in the southern hemisphere (39). In developed countries including England, Australia and New Zealand, most of the hospital-based studies for depressive disorder and seasonality reported evidence of a spring/summer peak incidence for depressive disorders (42-44).

Currently, some data have identified more summer cases for schizophrenia and ambient temperature were also assumed to take part in the emergency of psychotic exacerbation (45). There were more hospital admissions for schizophrenia in the summer time and for schizoaffective disorders in the fall season as reported in a study in Israel (46). Research in the northern hemisphere including Ireland, England, and Scotland showed that first hospitalizations for schizophrenia were influenced by seasonality, and the peak of cases for mental disorders occurred during the summer season (45, 47). A report from the Norwegian Hordaland health study illustrated that seasonality had a positive relation to levels of both anxiety and depression (48). Furthermore, studies from Asian countries such as Korea, Taiwan and India indicated that there was seasonal variation in depressive disorders among hospital admissions (49-51). Korean researchers found that the occurrence of the first manic episode was related to a seasonal variation, with peaks in the spring and fall periods in which there was significant associations with hours of sunshine and sunlight radiation (50). Another study from Taiwan with a five-year population-based dataset examining seasonal and climatic variations in bipolar disorder admissions revealed that there was significant seasonality in all three subtypes of bipolar disorder mood episodes (49). Researchers in India found that the prevalence of seasonal affective disorder was approximately 5.7% which increased to around 10% in cases with re-current mood disorder; further, there was strong
evidence of seasonality-related mania, either alone or in conjunction with seasonal depression (51).

5. The association between extreme heat/heatwaves and mental health

Various indicators have been applied to evaluate the relationship between heatwaves and psychiatric problems including hospital admissions, outpatients, emergency department visits, and ambulance call-outs (52-56). These discrepancies of heat-associated mental illness may be related to the difference in regions, weather, and demographic characteristics of the study sites and various study designs (5, 57). The vulnerable populations impacted by heatwaves differed in gender and age groups (58-60). The elderly, children, and men were more susceptible than other groups in which the group over 65 years of age was the most vulnerable for heat-related mental disorders (61-65).

Elevated levels of psychiatric disorders due to heat/extreme heat exposure have recently been reported in developed nations particularly in Australia, USA, and Canada (29, 66-68). In addition, the risk of mortality increased among patients with mental disorders taking psychotropic drugs during heatwave events in several nations including Australia, Italy, France, England and Spain (55, 69, 70). The Australian study (2008) found a relationship between heatwaves and mental behavioral as well as cognitive disorders (29). The study reported that issues on heat effects on mental health disorders were addressed including the nature of mental disorders triggering mortality and morbidity related to heat effects (29, 71).

Another study in Canada (2014) examined acute impacts of extreme temperature exposure on increased admissions for mental and behavioral disorders, and for high temperatures both general and specific mental disorders were significantly associated; however, no relation was found for cold weather (68).

The research showed that extreme weather had triggered a high proportion of psychological problems among vulnerable populations such as children and residents in remote areas (8). In New South Wales, Australia, the rates of suicide and self-injuries increased by 8% after experiencing a long severe drought (30). Furthermore, many study results have shown heat related to violence, conflicts, and threats to mental health, anxiety and despair (29, 72, 73). Australian scientists also proved that elderly populations from 65 to 74 years of age and residents in rural areas had the highest risk of heat-associated mental and behavioral disorders (29, 74-76). Heat/extreme heat events may impact interpersonal and intergroup behavior, triggering an
increased stress and anxiety (8). Even, the awareness and fear of climate change-related consequences by indirect effects may threaten human mental health (77-79).

A few studies on heat-related mental illness from developed countries such as Australia (2008) and Canada (2014) have indicated an existence of the relation (29, 68). However, there have been limitations of such studies worldwide. Hence, further research is needed especially in developing nations with global warming impacts like Vietnam.

6. Vietnam: temperature variations, mental health problems, and some effects due to climate change in future

Vietnam has spurred a quite rapid economic growth and infrastructure starting in 1986 (80). There was an increase in per capita income in Vietnam from around 100 USD in the 1980s to 2,100 USD in 2015 (80). Almost the entire Vietnamese population, with Confucian roots and Buddhism background, has traditionally had a sense of community (81). Vietnam has 95 million inhabitants, out of which seventy-three percent of the population lives in rural areas with over 60 million working in agriculture (51, 82, 83). Farmers and fishermen have faced increased difficulties suffering consequences of global warming in which the rising temperature is of severe impact (3, 84).

6.1. Temperature variations

Vietnam located in the subtropics suffers annual natural disasters including tropical storms, floods and especially extreme heat (85). The nation had a high risk of negative effects from global warming with temperatures increasing by 0.5-0.7°C per 50 years from the South to the North, and the frequency of cold fronts decreasing by 2.45 events per 50 years (85).

In Hanoi, the mean temperature was between 23.3°C and 23.6°C, with the lowest in the decade 1931 – 1940. The mean temperature in July had an increased trend between 1930s and 1990s from 28.6°C to 29.3°C (85) (Fig 2).

Furthermore, table 1 illustrates the mean temperature in all regions of Vietnam, projected to rise by 1.6 – 1.9°C and 1.9 – 2.2°C in the years of 2050, and 2070, respectively, compared with the period 1980 – 1999 (85). Moreover, the increased trend in temperature in the northern part of Vietnam will be higher than that in the southern of Vietnam in 2070 (85).
Table 1. Projections of the temperature in regions of Vietnam in 2050 and 2070

<table>
<thead>
<tr>
<th>Factors</th>
<th>Region</th>
<th>Year 2050</th>
<th>Year 2070</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature increase (°C)</td>
<td>North West, North East</td>
<td>1.0</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>North Delta</td>
<td>1.1</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>North Central</td>
<td>1.1</td>
<td>1.5</td>
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<tr>
<td></td>
<td>Middle of Central</td>
<td>1.1</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>South Central</td>
<td>1.1</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Central Highlands</td>
<td>1.8</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>South</td>
<td>1.1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Source: Asian Development Bank, Climate Change in Asia (12)

Source: The Vietnam Assessment Report on Climate Change (VARCC) 2009 (85)

Fig 2. The trend of annual mean air temperature in Hanoi in the last century
Impacts of global warming such as rising temperatures and more often heatwave occurrence pose a particular stress on many ecosystems, species including human beings globally, but also for Vietnam (10). The question is if there is a balance in a sustainable development between human health and economic growth due to environmental impacts as an increased carbon level? The sustainability of human health must be a central consideration in the public discussion on how human societies can make a transition to sustainable development especially among developing countries (86). This must be a really big challenge for governments in developed countries, and particularly in LMICs like Vietnam.

6.2. Mental health problems

In terms of mental health problems, mental and depressive disorders have increasingly become a burden of disease affecting economic, social and cultural developments in Vietnam (87, 88). A study on ten common mental disorders in 2010, illustrated that there was 14.9% of the population, equal to approximately 14 million of Vietnamese people, suffering from mental health problems such as depression, schizophrenia, anxiety disorder, alcohol abuse and drug abuse (21, 82, 89). According to statistical data from the Ministry of Health there were three diagnostic groups of patients including schizophrenia, schizotypal and delusional disorders (60%), mood disorders (15%), and neurotic, stress-related and somatoform disorders (15%) in several Vietnamese mental hospitals (88, 90).

Studies regarding alcohol abuse showed that 16.3% of the men were at risk of becoming dependent on alcohol 7.9% were alcohol dependent and approximately 2% were harmful users (91). There were 66.7% of men between the age of 25 and 44 years that consumed more than three standard drinks per day in the previous month, a notably higher rate than men aged 45–64 years (59%) and men aged 65–74 (53.4%) (91, 92). The prevalence of alcohol consumption-related problems was 25.5% for men and 0.7% for women (92).

Another national community-based study among 14–25 years old revealed that 32% had sad feelings about their life in which 25% of them felt so sad or helpless that they could no longer engage in their normal activities, 21% felt disappointed about their future, 0.5% reported to have had a suicide attempt, and 2.8% had tried to hurt themselves (88). Young males, particularly among 18–21 year old had the highest suicide attempt rate with 6.4%, with 4.1% of them living in urban and rural areas (88, 93). There were estimates of prevalence rates for suicide of 8.9% for life-time suicidal thoughts, 1.1% for suicide plans and 0.4% for suicide attempts (94). The finding of suicidal thoughts associated with risk factors such as negative
psychosocial, lifestyle and emotional problems was similar to those in Western countries and other Asian countries (88, 94).

6.3. Vietnam and policy issues related to mental health care system

Although mental health problems have increased in Vietnam, Vietnam’s mental health policy is less efficient to meet the demand for current mental problems (14). The policy was last revised in 1989 (81), and a national plan of action on treatment of schizophrenia and epilepsy in hospitals was set up in 2004 (88). The mental health system is integrated into the public health system in Vietnam, in which the health care system is classified into four levels that include the central, provincial, district and community levels with psychiatrists working at the central and provincial levels (88). The activity of the mental health system is organized from the national psychiatric hospital to the community level (81). In Vietnam, however, mental health services in hospitals are provided with more resources, both human and material, than those in the community, especially human resources for mental health care such as psychiatrists and psychologists (14, 88). The plan for the five years between 2006 and 2010 set up the main objective to support mental health services at the community level through mobilizing community resources (81). The overall objectives were to cover all communes and include early diagnosis and treatment for epilepsy and depression up to 2010 (81, 95). Moreover, the activities of this program included mental health training of health staff and health collaborators, as well as household surveys to identify depression and epilepsy patients; it also included delivering monthly medicines for patients, monitoring and supporting patients for mental health problems through medicine and health education through village media (81, 88).

There have been approximately 50% of the population with free access to essential psychotropic medicines but almost all of them must pay out-of-pocket, and a few severe mental disorders are covered by social policy schemes such as schizophrenia and epilepsy (96). The National health services is involved in the planning, management and coordination, and the monitoring and quality assessment of mental health services (88). There were about 2-5% of patients restrained by mental hospitals; the remainder of patients went to mental hospitals with the occasion of severe cases (96). Due to paying out-of-pocket, there has been an inequity of access to mental health services for other minority users (e.g., linguistic, ethnic, religious minorities) in Vietnam (96).

Financially, mental hospitals have been entirely subsidized by the government in which the government has paid for control and medication of epilepsy and schizophrenia, whereas medication and treatment for other
mental illnesses has been paid out-of-pocket (82, 97). Every year the Vietnamese government spends approximately two million USD on mental health, compared to 46 million USD allocated in Thailand in 2004; these amounts are much less than in developed countries (14, 88, 98). Furthermore, no regular national programs for information on the promotion of mental health through public education and awareness campaigns have been held that target the general population and health care providers, leaders and politicians (14, 81).

6.4. Urbanization in Vietnam

There was a dramatic change in trends and patterns in urbanization in Vietnam over the last decade in which the population in all cities or provinces, especially in the two biggest cities such as Ho Chi Minh City and Hanoi, increased dramatically by over ten percent (99). Other provinces and central city-provinces increased from five to ten percent (99, 100). Population in urban areas increased 10% in 1950 and 21.5% in 1975 (99). However, there were significant differences between the north and the south due to the war in which the level of urbanization decreased slightly in the north and increased substantially in the south. After 1975, there was a change in population from urban to rural areas with a substantial decrease by 18.4% because the government encouraged Vietnamese citizens to focus on the agriculture area (99). Up to 1986, urbanization increased owing to the demand of economic growth (100). From 1986, the level of urbanization continued to increase from 20% to 29.6% in 2009 (99). There was a difference of urbanization between cities; in Ho Chi Minh City in the southeast the population increased from 30.1% to 57.1% during 1995 – 2009 and in Hanoi in the Red River delta the population in urban regions increased from 19.9% to 29.2% (99). Moreover, urbanization in Vietnam has gone up gradually from 31.3% to 33.59% for 5 recent years (2010 – 2015) (101).

There are many reasons leading to urbanization in which the impacts of climate change have nowadays played a role (13). Vietnam shows an increased trend in urbanization from areas with high impacts due to climate change to important cities such as Ho Chi Minh City and Hanoi (99, 100, 102, 103).

6.5. The characteristics of weather in Vietnam and some effects due to climate change in future

Vietnam is one of the nations in the Asian region that suffers highly vulnerable to climate change and natural disasters (13). It is a coastal country with a long monsoon-affected coastline and a number of major river deltas. Over the decade 1997-2006, approximately 7,500 lives were lost because of
natural disasters especially tropical storms and floods (104). Moreover, poverty gains were fragile with one-third of the population falling into the ‘poor’ or ‘near poor’ groups (84). These groups may be highly vulnerable to effects from climate change, and natural disasters, as well as economic and health problems (84). An estimate of average economic losses for climate change consequences amounted to 1-1.5 percent of GDP (Gross domestic product) over the past two decades (84).

The adaptations and mitigations have been set up by Vietnamese government to reduce disaster risks for the country in which the Vietnamese Government established the decrees such as “National Strategy for Natural Disaster Prevention, Response and Mitigation to 2020” in 2007 and the “National Target Program to Climate Change Response” in 2008 (104). In Vietnam, the Ministry of Natural Resources and the Environment is the head agency for climate change coordination, while the Ministry of Agriculture and Rural Development maintains overall responsibility for rural development and disasters (105). Moreover, many international organizations such as the Australian Agency for International Development, the United Nations Development Program, the United Nations Office for Disaster Risk Reduction, and the World Bank’s Global Facility for Disaster Reduction and Recovery have played supporting and assisting roles in the development of strengthened activities aimed at mitigating consequences of climate change in Vietnam (105). Generally, the National strategy for preventing the impacts due to climate change on population has been aimed at guaranteeing food security, energy security, water security, poverty reduction, gender equality, social security, public health, and better livelihood as well as to protect natural resources in the context of climate change (84, 104).

Moreover, the prevalence of mental health disorders has emerged and also psychiatrists and psychologists have been significantly inadequate especially in rural region (89, 106, 107). Thus, like many poor countries, mental health provision in Vietnam has been hugely insufficient and unlikely prioritized for the capacity of economic and mental resources in response to extreme weather occurrence (78).

Vietnam, however, has limited data from studies on the relationship between climate change, weather variations and potential health problems – both physical and mental. Thus, the studies in this thesis will be carried out to describe and examine the relationship between weather patterns, extreme heat/heat wave exposure and mental disorders – both all and specific hospital admissions; also the aim is to recognize risk factors contributing to increased vulnerability and susceptibility.
Objectives

Main objective

To examine relationships between weather patterns, extreme heat and mental disorders; and to study factors contributing to increased vulnerability and susceptibility.

Specific objectives

1. To assess the relation between exposure to heatwaves and mental disorders globally.
2. To study the association between weather patterns, seasonality, heatwaves and mental disorders; and to identify factors contributing to increased vulnerability and susceptibility in Hanoi, Vietnam.
Methods and materials

1. **A systematic review and Meta-analysis**

*Data sources and searches*

The guideline of the PRISMA Statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses with a focus on health equity) was used in a systematic literature review (108). Electronic databases searched in MEDLINE, EMBASE, and Web of Science using search terms for mental health defined by the International Classification of Diseases (ICD 9 – 10) or the Diagnostic and Statistical Manual of Mental Disorders (DSM –IV, V) criteria (2, 109). The keywords of heat (heat, extreme heat, heatwave, heat stress, heat shock, and hot weather) and mental (mental health, mental disorder, mental illness, mental disease, behavioral disorder, psychiatric disorder, and morbidity) were applied. English-language studies on human subjects published between 01/01/2000 and 31/03/2016 were involved in the study.

*Study selection*

The eligibility of studies was confirmed (1) if they constituted original research studies presenting primary data that used an observational study design (i.e. population-based studies, ecological studies with or without time series analysis); (2) if they presented appropriate effect estimates (e.g. odds ratio, risk ratio, correlation coefficient, % change, etc.) in morbidity, change in morbidity, or excess morbidity; (3) if they reported heatwaves at least three consecutive days with at least 95% percentile of ambient temperatures as the main exposure of interest; (4) if they analyzed mental disorders as the main outcome.

*Data extraction*

From all eligible studies, we abstracted the following information: first author’s name, year of publication, country, year of data collection (including follow-ups), sample size (including information on age and sex), mental health morbidity under study and effect size, control variables/confounder assessment, type of population (e.g. population study, inpatient, outpatient, etc.; including information on control or comparison groups), method of diagnosis or self-report, as well as information on the heatwave exposure.
**Meta-analysis method**

Outcome data extracted from clinical studies were grouped by domain (mental disorders with all cases, mental disorders with specific cases, heatwave exposure with ≥ 3 consecutive days, studies with time series analysis, studies without time series analysis, population with aged 65-74, and over 74, and nations). In each domain, similar constructs were grouped together for meta-analysis. One article with several heatwave events was evaluated as several studies, each corresponding to specific events. There were at least two studies with the same exposure (heatwave exposure with ≥ 3 consecutive days) or outcome (mental disorders with all cases or mental disorders with specific cases) analyzed as a meta-analysis on the outcome.

In the study, analyses were carried out using Stata 13 software. In addition, random effects were included in all analyses to estimate study specific heterogeneity (110).

2. **Hospital-based study**

**Study setting**

Located at 21°2′0″N 105°51′00″E, Hanoi has typically subtropical weather with four defined seasons – spring (March-May), summer (June-August), autumn (September-November), and winter (December-February). Hanoi’s area of 3,329 km² includes 13 districts (referred to as the urban area) and 17 suburbs (referred to as the rural area). Hanoi, the capital of Vietnam, has a population of approximately seven million people living in a typically subtropical climate. In recent years, the mean daily temperatures have increasingly risen in Hanoi, likely resulting from climate change and urbanization (111). Meteorological data including daily mean ambient temperature, humidity, and the hours of sunshine were collected from several monitoring stations in Hanoi during 24-hours per day. Each climatic parameter was estimated by a mean value. The daily mean values of ambient temperature both mean and maximum were applied to examine its association to the prevalence of mental disorders between 2008 and 2012.
Hospitalization data

Hanoi Mental hospital is one of two big mental hospitals taking care of mental patients in Hanoi City. Both inpatients as emergency visits and outpatients in Hanoi and neighboring provinces have access. There were 420 beds for inpatients and 38 physicians for treatment of mental patients in the hospital. In the study, a database from Hanoi Mental hospital that covered mainly emergency cases for mental disorders in Hanoi City between 01 January 2008 and 31 December 2012 was used.

The database from Hanoi Mental Hospital covering five years from 2008 to 2012 was used and included all patients with mental diseases in the north of Vietnam (including Hanoi). The hospital admissions were diagnosed by ICD 10 by mental health specialists. Mental health disorders were classified according to ICD 10 in groups by diagnosis codes: F00 to F99. The group of mental disorder (F) was divided into nine groups (2):

1. Organic, including symptomatic, mental disorders (F00-F09),
2. Mental and behavioral disorders due to psychoactive substance use (F10-19),
3. Schizophrenia, schizotypal, and delusional disorders (F20-29),
4. Mood (affective) disorders (F30-39),
5. Neurotic, stress-related, and somatoform disorders (F40-48),
6. Behavioral syndromes associated with physiological disturbances and physical factors (F50-59)
7. Disorders of adult personality and behavior (F60-F69)
8. Mental retardation (F70-79).
9. Unspecific mental health (F99)

However, all admissions for mental disorders in Hanoi Mental hospital during the five years (2008 – 2012) were F0-9, F10-19, F20-29, F30-39, F40-48, F50-59, F70-79, and F99; the exception was F60-69. Thus, relations of mental disorders were evaluated by both general and specific hospitalizations.

**Statistical analysis**

Time-series regression analysis aims to understand how time varying extraneous variables influences an outcome over time. However, often time series violates the key assumption of standard regression methods assuming independence of the dependent variable (112). This makes it important to assess residual dependence after the model has been fitted and adjusted for the time varying extraneous variables. The conventional time series regression approach in environmental health studies includes controlling for potential unmeasured confounding variables, such as long-term time trends and season, air pollution and influenza epidemics (113, 114). In studies of short-term impacts of environmental stressors, such as temperatures on health outcomes, the unmeasured time components adjusted for include: between-year trends; within-year trends (seasons); and the daily variability is left to be associated with the outcome but adjusted for other potential confounders varying from day to day (112). Such short-term potential confounder include calendar patterns, such as weekdays and national holidays (112).

Estimating the variation in the counts of events related to ambient temperatures on the same day and on previous days (so-called lagged effects) is a common purpose of studies in public health as there is often latencies between the exposure and the effect (113, 115). Statistical approaches focus on regression methods within the generalized linear model (GLM), or generalized additive model (GAM) frameworks (113). Determining the most appropriate distribution, and link function, of the regression model depends
on the nature of the distribution of the outcome variable. Count data are usually assumed Poisson or negative binomial distributed (116). Count data series with over-dispersion, e.g. when the mean is smaller than the variance, are better fitted using the negative binomial distribution function, or a quasi-Poisson distribution (113).

The exposure-response functions are commonly modelled as smooth functions, e.g. such as natural cubic spline functions, and so are adjustment for time trends. The advantage of smooth functions are that they can capture complex non-log linear relationship between exposure/confounders and effects (114). Other common spline functions are the piecewise-linear function in which thresholds and changes in the linear exposure-response relationship can be estimated using maximum-likelihood algorithms (116). Threshold parameterization to describe linear effects of cold and heat below and above specific cut-off temperatures are examples of linear piecewise spline functions. In general, spline functions can be modeled either within standard generalized linear (GLM) as parametric function, or using a semi-parametric generalized additive modeling (GAM) framework. In the latter, the flexibility of the spline functions is interactively shrunk from a maximum specification during iterative model fitting (113). Recently, a single spline function of time has been increasingly used, producing an irregular seasonal trend which is believed to control for additional confounding effects functioning at long and medium timescales (113). The type of spline, and the modelling framework, is important when selecting the appropriate amount of smoothing. The smoothing in general is aimed at avoiding residual confounding, which if left uncontrolled, is violating the independent assumption of the standard regression models. The degree of flexibility of splines is determined by the selection of the number of (effective or maximal) degrees of freedom (df) per year (112, 113).

(1) In this study, the time series model included 1827 days and 619 admissions for depressive disorders from 1 Jan 2008 to 31 Dec 2012 collected from Hanoi Mental hospital. Using a negative binominal regression model, a relationship was estimated for the average of the collective values between the occurrence of daily admissions and lags of weather patterns. To estimate and to adjust for annual and seasonal time, seasonality, factor variables were included for day of week, month and year as explanatory variables. In this study, several models were used (i) a log-linear function was applied to determine the relationship between weather variables, seasonality and admissions; (ii) weather parameters were included as the mean, over 0–1 day, 0–6 days, and 0–13 days to account for potential delayed exposure effects.
(2) A Negative Binomial regression model was applied to estimate the association between 23525 daily hospitalizations for mental disorders (including F00 – F99), and seasons adjusted for the year of study period. Seasons were defined as spring (March to May), summer (June to August), autumn (September to November) and winter (December to February). In addition, this model was also used to associate elevated temperature to mental illnesses adjusted by time trends, the day of week, and the period of study between 2008 and 2012.

(3) In parallel with Negative Binomial regression, Zero-inflated Binomial regression models were applied to quantify the relationship of 21443 daily hospital cases over the period 2008-2012 of mental disorders (involving F00 – F79) with heatwaves, compared with the referent period being all non-heatwave days. The relationship was adjusted by time trends with 16 degrees of freedom (seasonality), the year of study period, and the day of week.

Weather data and patterns

During five years (2008-2012), the average maximum temperature in Hanoi was about 32°C in hot months (May to September), with a standard deviation of ± 3°C. Furthermore, the threshold of maximum temperature being 35°C was mainly studied as 90th percentile, and defined heat waves as ≥ three consecutive days and ≥ seven consecutive days when the daily maximum temperature (T-max) reached or exceeded 35°C of daily maximum temperature. Most of the heatwave definitions are based on the condition of meteorological aspects and the relative occurrence of the event, and few of them are based on physiological thresholds for thermal stress (117, 118). None have been developed to capture mental stress physiological reactions and mechanisms (117). According to some researchers, it is important to establish an appropriate definition of heatwaves locally in relation to its health impacts (119). However, it appears desirable to have a dynamic and flexible definition of heatwaves when population characteristics, epidemiological profiles of populations and climate conditions may change over time and modify health impact, both physical and mental health (117). Thus, in recent studies, a definition of heatwaves was used to evaluate the effect of heatwaves in relation to hospitalizations based on threshold of temperatures (29, 68, 120-122).

Moreover, hospital admissions for mental disorders was analyzed collectively and with stratification by age groups (0 -17; 18 – 40; 41 – 60; and ≥ 61 years), sex, and location. We adjusted for long-term, time trends and
seasonal patterns. Results are shown as incidence rate ratios (RRs) with 95% confidence intervals (CIs).

3. Ethics Statement

Electronic health data sets, including the code, age, sex, date, and treatment of admissions for mental disorders, both children and adults, were anonymized and de-identified prior to analysis. All procedures were approved by the Hanoi Medical University and the Mental Hospital Ethics Board in Vietnam.
Results

1. Heat-related mental illness on a global level

Several studies conducted in Australia on the relationship between heatwaves and mental disorders reported relative risks among the general population, old people of 65-74 years, and over 74 years. Results showed that the risk of mental illnesses due to heatwave exposure among the elderly with 65-74 years (1.12, 1 – 1.26) and for over 74 years (1.16, 1.1 – 1.21) was higher than the risk of mental disorders among the general population (1.05, 1.01 – 1.08) (Fig. 3).

![Relative risks of studies on heatwaves-related mental illnesses among general population and elderly over 65](image)

*Fig 3. Relative risks and 95% confidence interval for studies on heatwaves-related mental illnesses among the general population and elderly over 65 years.*

In addition, available articles with time series analysis from developed nations mainly Australia and the United States, showed there was an association between heatwaves and mental disorders with a combined relative risk of 1.3 (1.03 – 1.65). The range of the relative risks was between 0.87 and 3.68 (Fig 4).
However, the combined relative risk among the research from the United States of 1.99 (1.34 – 2.95) was higher than those from Australia 1.03 (1.01 – 1.05).

<table>
<thead>
<tr>
<th>Study ID</th>
<th>RR (95% CI)</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hansen et al. 2008</td>
<td>1.07 (1.02, 1.13)</td>
<td>5.07</td>
</tr>
<tr>
<td>Monika Nitschke et al. 2007</td>
<td>1.07 (1.01, 1.13)</td>
<td>5.07</td>
</tr>
<tr>
<td>Behnoosh Khalaj et al. 2010</td>
<td>1.07 (1.00, 1.14)</td>
<td>5.06</td>
</tr>
<tr>
<td>Monika Nitschke et al. 2011</td>
<td>1.05 (1.00, 1.10)</td>
<td>5.07</td>
</tr>
<tr>
<td>Monika Nitschke et al. 2011</td>
<td>0.98 (0.84, 1.14)</td>
<td>4.97</td>
</tr>
<tr>
<td>Monika Nitschke et al. 2011</td>
<td>1.03 (0.88, 1.21)</td>
<td>4.97</td>
</tr>
<tr>
<td>Susan Williams et al. 2012</td>
<td>1.02 (0.99, 1.05)</td>
<td>5.08</td>
</tr>
<tr>
<td>Xiao Yu Wang et al. 2012</td>
<td>0.87 (0.70, 1.08)</td>
<td>4.87</td>
</tr>
<tr>
<td>Leigh Ann Wilson et al. 2013</td>
<td>1.05 (0.99, 1.11)</td>
<td>5.07</td>
</tr>
<tr>
<td>Pavla Vaneckova et al. 2013</td>
<td>1.01 (0.98, 1.04)</td>
<td>5.08</td>
</tr>
<tr>
<td>Tania Busch Isaksen et al. 2015</td>
<td>0.93 (0.83, 1.04)</td>
<td>5.02</td>
</tr>
<tr>
<td>Ying Zhang et al. 2013</td>
<td>1.05 (0.71, 1.55)</td>
<td>4.47</td>
</tr>
<tr>
<td>Subtotal (I-squared = 21.8%, p = 0.229)</td>
<td>1.03 (1.01, 1.05)</td>
<td>59.79</td>
</tr>
<tr>
<td>Canada</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xiang Wang et al. 2014</td>
<td>1.29 (1.09, 1.53)</td>
<td>4.95</td>
</tr>
<tr>
<td>Subtotal (I-squared = .%, p = .)</td>
<td>1.29 (1.09, 1.53)</td>
<td>4.95</td>
</tr>
<tr>
<td>USA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satish K. Pillai et al. 2014</td>
<td>3.68 (3.08, 4.40)</td>
<td>4.94</td>
</tr>
<tr>
<td>Jeremy J. Hess et al. 2014</td>
<td>2.84 (2.66, 3.03)</td>
<td>5.06</td>
</tr>
<tr>
<td>Michael T. Schmeltz et al. 2015</td>
<td>1.83 (1.79, 1.87)</td>
<td>5.08</td>
</tr>
<tr>
<td>Bo Li et al. 2012</td>
<td>2.70 (2.67, 2.73)</td>
<td>5.08</td>
</tr>
<tr>
<td>Christopher M et al. 2016</td>
<td>1.52 (1.35, 1.71)</td>
<td>5.02</td>
</tr>
<tr>
<td>Christopher M et al. 2016</td>
<td>0.96 (0.94, 0.98)</td>
<td>5.08</td>
</tr>
<tr>
<td>Christopher M et al. 2016</td>
<td>1.64 (1.43, 1.88)</td>
<td>5.00</td>
</tr>
<tr>
<td>Subtotal (I-squared = 99.9%, p = 0.000)</td>
<td>1.99 (1.34, 2.95)</td>
<td>35.25</td>
</tr>
<tr>
<td>Overall (I-squared = 99.9%, p = 0.000)</td>
<td>1.30 (1.03, 1.65)</td>
<td>100.00</td>
</tr>
</tbody>
</table>

**Fig 4.** Relative risks and 95% confidence interval (CI) for studies on associations between heatwaves and mental disorders.
2. Heat-related mental illness in Hanoi, Vietnam

2.1. Weather variations in Hanoi during five years (2008-2012)

Figure 5 shows that monthly temperatures expressed as mean and maximum were high in the summer season and the hottest period in Hanoi, Vietnam was between May and Sept.
Fig 5. Variations in monthly mean humidity and temperatures including mean and maximum during five years (2008-2012).

Table 2. Mean values of climatic patterns and heatwave events from 2008 to 2012.

<table>
<thead>
<tr>
<th>Climatic variables</th>
<th>Mean ± SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean temperature (°C)</td>
<td>24.3 ± 5.6</td>
<td>7.4</td>
<td>34.5</td>
</tr>
<tr>
<td>Maximum temperature (°C)</td>
<td>28 ± 6.3</td>
<td>8</td>
<td>40.4</td>
</tr>
<tr>
<td>Humidity (%)</td>
<td>78.2 ± 9.8</td>
<td>41</td>
<td>98</td>
</tr>
<tr>
<td>Hours of sunshine (hour)</td>
<td>3.3 ± 3.2</td>
<td>0</td>
<td>11</td>
</tr>
</tbody>
</table>

Events of heatwaves at maximum temperature exceeding 35°C

| Maximum temperature (°C) | 32 ± 3 °C between May and September |
| Heatwaves one day | 175 events with lag 0 |
| Heatwaves three days | 61 events with lag 0-2 days |
| Heatwaves seven days | 10 events with lag 0-6 days |

Hanoi, Vietnam, has four definite seasons – spring (March-May), summer (June-August), autumn (September-November), and winter (December-February). It also had an average of yearly mean maximum temperature during 2008-2012 around 28°C with the maximum of 40.4°C. The monthly mean temperature in the winter and in the summer was the lowest around 18-21°C and the highest around 33°C. In Hanoi, hot weather conditions usually extend from May to September, and during the five years (2008 – 2012) the average maximum temperature was around 32°C with a standard deviation of ± 3°C (Table 2). Furthermore, over five years 175 single
days were observed with a maximum temperature exceeding 35°C. Of those days 61 included at least three consecutive days of this condition, and ten events of these included at least seven consecutive days of this condition (Table 2).

2.2. Characteristics of the study population

Fig 6. Descriptive statistics of the admissions for mental disorders at the Hanoi Mental Hospital from 2008 to 2012.
The hospital data used throughout the period of the study (2008-2012) showed 23525 subjects with mental health disorders that were both inpatients and outpatients with the first time registered in the mental hospital (Fig 6). Specific psychiatric patients included 1530 (6.5%) for F0-9, 3963 (16.8%) for F10-19, 11381 (48.4%) for F20-29, 620 (2.6%) for F30-39, 508 (2.2%) for F40-48, 1002 (4.3%) for F50-59, 2439 (10.4%) for F70-79, and 2082 (8.8%) for F99 (Fig 6). In this study, the group of F60-69 had non-patients and 619 of 620 admissions for F30-39 were F30-33.

Moreover, the males and females were 17546 (74.6%) and 5979 (25.4%), residents in urban and in rural were 13486 (57.3%) and 10017 (42.5%), respectively. Age groups including 0-17, 18-40, 41-60, and over 60 were 734 (3.1%), 11645 (49.5%), 9380 (39.9%) and 1766 (7.5%), respectively (Fig 6).

The number of cases for specific psychiatric disorders (F00-99) among men were higher than those among women especially in the group of F10-19 and F20-29. However, in the groups of F30-39, F40-48, and F50-59, admissions among women were higher than those among men (Fig 7).

![Gender difference for mental disorders](image)

**Fig 7. Gender difference among hospital admissions for specific mental disorders**

The location difference analyzed in this study illustrated that there was a difference in patients between rural and urban regions. Patients in urban areas were higher than those in rural areas with 57.4% and 42.6%, respectively. Moreover, regarding specific mental disorders, admissions for F20-29 (schizophrenia) in urban areas were twice as high as those in rural areas. However, the number of hospitalizations for other groups including
F30-39 (mood affective disorder), F70-79 (mental retardation), and F99 (unspecified mental disorders) in urban regions were less than those in rural regions. Figure 8 shows that, except for F10-19, F20-29, and F70-79 there was not much difference in patients between rural and urban areas.

![Location difference for mental disorders](image)

**Fig 8. Location difference among hospital admissions for specific mental disorders**

![Inpatients and outpatients for mental disorders](image)

**Fig 9. The difference between inpatients and outpatients among hospital admissions for specific mental disorders**
There were two kinds of patients that included inpatients and outpatients that were accessed at the Hanoi mental hospital between 2008 and 2012. Inpatients were defined as acute admissions for mental disorders in which some of them were admitted in the hospital with several episodes as emergency cases. Outpatients were described as new patients with the first registration. Because almost all outpatients except for the first episode, with other episodes were planned by medical doctors. Our database for five years indicated that inpatients for F0-9 (organic mental disorders), F10-19, F20-29, F70-79, and F99 were higher than outpatients. This was not the case for F30-39, F40-48 (neurotic, stressed-related, and somatoform disorders), and F50-59 (behavioral syndromes associated with physiological disturbances and physical problems).

In this study, there were 23525 episodes of admissions for mental disorders that included 82.1% inpatients and 17.9% outpatients. Thus, there was a sharply significant difference between inpatients and outpatients. The inpatients with acute cases were four-fold higher than outpatients with first registered in the hospital during the five years (Fig 9).

2.3. The relationships between hot weather, heatwaves and depressive as well as other mental disorders

![Graph showing the association of admissions for depressive disorders and mean temperature variation](image)

**Fig 10.** Hospital admissions for depressive disorders and mean temperature as well as the delay of one, seven, and 14 days

Regarding the relationship between weather patterns and depressive disorders, there were statistically significant linear associations between admissions for depressive disorder and mean ambient temperature.
Admissions among all populations had a quite high relative risk (RR=1.05, 1.01 – 1.09); for F31 (bipolar affective disorder) there was an increased trend at lag 0-1 day, lag 0-6 days, and lag 0-13 days (Fig 10).

In parallel with mean temperature-associated depressive disorders, there were also relationships between mean temperature and other mental disorders. Hospital admissions showed an increased trend in elevated mean temperature. The number of cases peaked in the hot months or summer season. These data are presented in figure 11.

![Graph showing mean temperature variation in hospital admissions for mental disorders](image)

**Fig 11. Mean temperature variation in hospital admissions for mental disorders**

The findings presented in figure 11 and table 3 indicated associations between hot weather exposures and mental disorders in which the peak of admissions, both all and specific, was in summer season especially among cases for F0-9 and F70-79 with RRs of 1.41 (1.14 – 1.75) and 1.36 (1.03 – 1.8), respectively. In addition, when temperatures elevated one unit (°C) hospital visits for mental disorders increased between 1% and 5% particularly among patients with depressive disorders (F30-39).
Table 3. The associations between mental disorders and seasonality and elevated mean temperature.

<table>
<thead>
<tr>
<th>Mental disorders</th>
<th>Relative risks and 95% confidence intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The peak of case related to seasonality</td>
</tr>
<tr>
<td></td>
<td>Elevated temperature</td>
</tr>
<tr>
<td>All</td>
<td>Summer (1.24, 1.1 – 1.39)</td>
</tr>
<tr>
<td>F0-9</td>
<td>Summer (1.41, 1.14 – 1.75)</td>
</tr>
<tr>
<td>F10-19</td>
<td>Spring (1.42, 1.23 – 1.64)</td>
</tr>
<tr>
<td>F20-29</td>
<td>Summer (1.15, 1.02 – 1.3)</td>
</tr>
<tr>
<td>F30-39</td>
<td>Autumn (1.33, 1.04 – 1.7)</td>
</tr>
<tr>
<td>F40-48</td>
<td>Summer (1.67, 1.25 – 2.25)</td>
</tr>
<tr>
<td>F50-59</td>
<td>Spring (1.07, 0.86 – 1.33)</td>
</tr>
<tr>
<td>F70-79</td>
<td>Summer (1.36, 1.03 – 1.8)</td>
</tr>
<tr>
<td>F99</td>
<td>Autumn (1.53, 1.3 – 1.81)</td>
</tr>
</tbody>
</table>

Table 4. The relationships between heatwaves and hospital admissions for mental disorders

<table>
<thead>
<tr>
<th>Mental disorders</th>
<th>Relative risks and 95% confidence intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heatwaves</td>
</tr>
<tr>
<td></td>
<td>Lag ≥ 3 days</td>
</tr>
<tr>
<td></td>
<td>Lag ≥ 7 days</td>
</tr>
<tr>
<td>All</td>
<td>1.15 (1.005 – 1.31)</td>
</tr>
<tr>
<td>F0-9</td>
<td>1.37 (0.97 – 1.95)</td>
</tr>
<tr>
<td>F10-19</td>
<td>1.05 (0.85 – 1.3)</td>
</tr>
<tr>
<td>F20-29</td>
<td>1.09 (0.94 – 1.27)</td>
</tr>
<tr>
<td>F30-39</td>
<td>0.98 (0.64 – 1.51)</td>
</tr>
<tr>
<td>F40-48</td>
<td>1.09 (0.7 – 1.73)</td>
</tr>
<tr>
<td>F50-59</td>
<td>0.97 (0.64 – 1.46)</td>
</tr>
<tr>
<td>F70-79</td>
<td>1.68 (1.08 – 2.62)</td>
</tr>
</tbody>
</table>

Regarding the relationship between heatwaves and mental disorders, table 4 shows heatwaves amounted to increasing risk for admissions among the whole group of mental disorders (F00-79) by relative risks (RRs) of 1.15 (1.005 – 1.31) and 1.36 (1 – 1.90) for heatwaves of at least three and seven days respectively. Admissions for F70-79 had a strong relationship to heatwaves of
at least three consecutive days with a RR of 1.68 (1.08 – 2.62). For seven consecutive days of a heatwave, the RR increased to 3.62 (1.7 – 7.42) for F0-9.

2.4. **Vulnerable and susceptible populations to hot weather and heatwaves**

*Table 5. The vulnerable and susceptible groups with mental disorders to hot weather*

<table>
<thead>
<tr>
<th>Groups</th>
<th>Relative risks and 95% confidence intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Seasonality</td>
</tr>
<tr>
<td>Male</td>
<td>Summer</td>
</tr>
<tr>
<td></td>
<td>(1.26, 1.12 – 1.41)</td>
</tr>
<tr>
<td>Female</td>
<td>Summer</td>
</tr>
<tr>
<td></td>
<td>(1.18, 1.03 – 1.36)</td>
</tr>
<tr>
<td>Urban</td>
<td>Summer</td>
</tr>
<tr>
<td></td>
<td>(1.28, 1.14 – 1.44)</td>
</tr>
<tr>
<td>Rural</td>
<td>Spring</td>
</tr>
<tr>
<td></td>
<td>(1.21 1.06 – 1.38)</td>
</tr>
<tr>
<td>Age 0-17</td>
<td>Summer</td>
</tr>
<tr>
<td></td>
<td>(1.29, 0.92 – 1.81)</td>
</tr>
<tr>
<td>Age 18-40</td>
<td>Summer</td>
</tr>
<tr>
<td></td>
<td>(1.26, 1.11 – 1.41)</td>
</tr>
<tr>
<td>Age 41-60</td>
<td>Spring</td>
</tr>
<tr>
<td></td>
<td>(1.23, 1.09 – 1.39)</td>
</tr>
<tr>
<td>Elderly &gt; 60 years</td>
<td>Summer</td>
</tr>
<tr>
<td></td>
<td>(1.23, 1.03 – 1.48)</td>
</tr>
</tbody>
</table>

In the summer season, hospital cases for mental disorders among male patients had higher risk with a RR of 1.26 (1.12 – 1.41) than those among female patients with a RR of 1.18 (1.03 – 1.36). The peak of cases among both men and women was in the summer season. Furthermore, the number of admissions among residents in urban areas had the greatest risk with a RR of 1.28 (1.14 – 1.44) in the summer time; whereas those in rural areas had the highest risk in the spring season with a RR of 1.21 (1.06 – 1.38) (Table 5).

Regarding the category of ages, RRs were high for almost all hospitalizations especially for the groups of 0-17 and over 60 years. The RR of mental disorders among patients 0-17 years of age was 1.29 (0.92 – 1.81) in summer time. The RR of mental disorders in the group of 18-40 years old was also elevated in the summer time with a RR of 1.26 (1.11 – 1.41). However, the number of cases in ages 40-60 years were estimated to peak in the spring
season with a RR of 1.23 (1.09 – 1.39). There was also an increase of 23% of hospitalizations (RR of 1.23, 1.03 – 1.48) for elderly over 60 years of age (Table 5). Thus, there was a positive relationship between seasonality and mental disorders stratified by sex, location, and age groups especially during summer season (Table 5).

At three days of heatwaves, the male patients and residents in rural areas were more sensitive than other groups with RRs of 1.15 (1 – 1.33) and 1.26 (1.04 – 1.52), respectively. At seven consecutive days of heatwaves, RRs of mental disorders were 1.69 (1.08 – 2.64) for residents in the rural area, 1.58 (0.98 – 2.52) for female patients, and 3.2 (1.63 – 6.29) for the age group over 60 years. Thus, patients with psychiatric disorders among residents in rural communities, in female patients and in the elderly population increased significantly during longer heatwaves (Table 5).

Regarding the relationship between heatwaves and specific mental disorders, heatwave-related mental illness (F0-9) was the highest risk at least seven consecutive days; whereas the highest risk of F70-79 was at least three consecutive days.

For admissions of F0-9, groups of F4-6, male, aged 41-60 years, over 60 years and residents in rural areas had high risks with RRs of 4.76 (1.74 –
13.18), 6.3 (2.1 – 19.5), 4.05 (1.51 – 10.88), 5.82 (2.09 – 16.25) and 7.82 (2.66 – 22.96), respectively. Therefore, the mental hospitalizations had an increased trend in time from three days to ≥ seven consecutive days of heat exposure in which the groups aged over 60 years and residents in rural areas accounted for the highest risks (Fig 12).

Fig 13. Mental disorders for F70-79 by daily maximum temperature (T-max) at lags, reached or exceed 35°C, stratified by sex, location and age (The left: heatwaves-related mental disorders at lag ≥ 3 consecutive days; the right: heatwaves-related mental disorders at lag ≥ 7 consecutive days)

Hospital visits for F70-79 had significant correlations to heatwaves especially for at least three consecutive days of elevated temperatures. There were high RRs of 1.65 (1.001 – 2.73) among males, 1.84 (1.12 – 3.02) among people aged 18-40 years, 1.83 (1.005 – 3.77) among over 40 years, 2.13 (1.28 – 3.53) among residents in urban areas, and 1.76 (1.11 – 3.04) among residents in rural areas (Fig 13).

Thus, the study results illustrated that (1) there were associations between extreme heat exposures including the hot summer time, elevated temperatures, heatwaves at the delay of three and seven days and mental disorders (both all and specific admissions) especially for F0-9 and F70-79. And, (2) the vulnerable and susceptible groups to hot weather and extreme heat were the elderly and residents in rural areas.
Discussion

Our world is currently under the pressure of the effects of global warming such as rising temperatures and more often heatwave occurrences (6). These may not only impact on ecosystem, but also on human health both physical and mental (6). Our main findings of the study conducted in the northern of Vietnam for five years (2008 – 2012) illustrated there were the relationships between hot weather, extreme heat and mental disorders especially among the groups of elderly over sixty years and residents in rural area. Thus, “Tackling climate change could be the greatest global health opportunity of the 21st century” (8). Health professionals worldwide and Vietnam in particular must mobilize to address the challenge, to protect human health, and provide for well-being for the future (10).

Uncovering the effects of climate change on human health and studying diseases and other aspects of poor health that are sensitive to extreme weather is very important (5, 6). In addition, it is important to examine the factors contributing to the susceptibility and vulnerability of populations and individuals impacted by changes of extreme weather (5). Also, describing actions to reduce the impacts of climate change on human health is crucial and meaningful especially for developing nations in the Asian region that is often suffering from the influence of climate change consequences (6, 12). These are very necessary not only for the world but also for Vietnam, a subtropical and low-and-middle income nation.

Recently, many studies on mortality and morbidity related to heatwaves have been carried out worldwide in which morbidity mainly focused on physical health problems including cardiovascular, respiratory, kidney, and infectious diseases (6). A few studies have been conducted on heatwave-associated mental illnesses in developed countries such as America and Australia (29, 68). However, no studies have reported on the relation between heatwaves and mental disorders in Asian nations where there are high impacts owing to global warming; these nations are developing countries with low-and-middle incomes (8, 71). Therefore, studying the relationship between mental disorders and exposure to hot weather and extreme heat, as well as to examine vulnerable groups to heat are crucial topics for Asian countries in general, and for Vietnam in particular.

Australian (2008) and Canadian (2014) studies illustrated that there were significant relationships between heatwaves and mental behavioral as well as cognitive disorders – both general and specific mental disorders (29, 68). The results reported that children, the elderly, and people in remote areas were vulnerable to extreme heat with a high risk of psychological problems.
Our findings were similar in which studies on heat-related mental illnesses in global and in the northern of Vietnam showed that the number of hospital admissions for mental disorders increased during hot weather and heatwaves. Moreover, older population and people in rural areas were vulnerable and susceptible groups to heat-associated mental illness.

1. Examining the associations between hospital admissions for mental disorders and exposure to hot weather and heatwaves.

In recent years, heat-related mental illness has become a challenge throughout the world (8). Several studies on heatwaves-related mental illness have been conducted in developed countries (6, 8, 12). However, almost no study has been conducted on heatwaves-related mental disorders in developing nations in Asian regions that have the most global warming impact compared with other areas (13).

Vietnam with approximately 95 million people is located in a subtropical area and it is difficult to avoid impacts of climate change such as tropical storms, floods, heatwaves and droughts (13). This may have influence on its economic growth with an estimate of 1-1.5 percent of GDP (Gross domestic product) loss over the past two decades due to climate change consequences (84). Moreover, prevalence of mental health problems has an increased trend, and the system for mental health care has not met the demand for the whole population, especially for the poor health groups (89, 106, 107). Data from studies on climate change-related mental health, weather-associated mental illness, and extreme heat-correlated psychiatric disorders have been limited in Vietnam. Particularly, hardly any studies on heat-associated mental illnesses have been conducted. Thus, findings in this thesis on mental disorders in relation to weather and extreme heat exposure are in need.

In the study, results showed significant correlations in admissions and the preponderance of hospital visits for depression; other mental disorders were in the warm period and heatwave events.

Considering the associations with variations in mean temperature and hours of sunshine, the higher the temperature and hours of sunshine the greater were admissions in the mental hospital for depressive disorders. Actually, the association between depressive disorders and exposure to elevated mean temperature and sunshine in this study showed an increase of daily hospital admissions including bipolar affective disorder and depressive episode when temperature and sunshine-hours increased a unit. Other countries in regions with temperate climates had different results because hospital cases for depressive disorders were elevated for lack of sunshine-
hours exposure (123-125). Moreover, at the delay of 14 days, the risk of cases appeared quite high when the daily hours of sunshine increased an hour. This could be due to heat-related mechanisms and interactions with the exposure to high temperature.

Furthermore, the result of seasonality-associated mental illness indicated that admissions for mental disorders peaked in the summer season with high temperatures in which groups of specific psychiatric disorders that included Fo-9, F20-29, F40-48, and F70-79 had the highest risks. Our data demonstrated positive associations between elevated temperatures per 1°C and mental admissions with an increased trend for all as well as for specific mental disorders especially for depressive disorders. This may explain an increase in the number of mental hospitalizations due to an increase in the summer period.

Compared with non-heatwaves, there were increased trends in the risks of admissions for three and seven consecutive days of heatwaves. The hospitalizations for mental disorders for heatwaves at least seven days were two-fold to those for heatwaves at least three days. Admissions for Fo-9 and F70-79 had the higher risk of mental disorders than other groups; hospital cases for Fo-9 and F70-79 increased significantly during heatwaves at least seven days and three days, respectively. The group of Fo-9 and F4-6 (delirium) had a strong relation to heatwaves. This may be explained by sociodemographic transitions due to high rates of alcohol abuse and traffic accidents especially among Vietnamese men (126, 127). Admissions for F70-79 had an increase for heatwaves at least three days. In Vietnam, around one million people with mental retardation are taken care of (128). Patients with mental retardation are often admitted in mental hospitals together with symptoms of other mental disorders such as schizophrenia, mood disorders, and anxiety (129). One big concern in the study was that the number of hospitalizations for schizophrenia were much higher than other groups and had an estimate of increase by 9% of admissions during heatwaves at least three days. Thus, study results indicated that the duration of heatwaves magnifies the impact on mental health disorders for all as well as for specific particularly Fo-9, F70-79, and F20-29.

The findings in this study were similar to results from Australia, the United States, and Canada (29, 68, 130). Santiago and colleagues in the United States claimed a statistically significant difference in relationship between ambient temperature and visits for psychiatric problems in emergency departments (131). In addition, Hansen et al in Australia also reported that admissions during 1993-2006 for behavioral and mental disorders were correlated with above a threshold of 26.7°C maximum daily
temperature (29). Similar outcomes were found in other nations such as France, Spain, India and Israel in which France, for example, had a high rate of visits in psychiatric emergency departments during the time of heat in 2003 (57). Almost all studies from both developed and developing countries showed a relationship between ambient temperature and schizophrenia and depression disorders; whereas there has been insufficient information for other specific mental diseases like dementia and drug and substance abuse (68). It was reported that the mean maximum monthly environmental temperature was associated with monthly inpatients for schizophrenia especially during the summer season (47, 132). In Israel and Taiwan, several studies showed the risk of admissions for schizophrenia was highly associated with mean maximal monthly temperature and increased temperatures (47, 132). Similarly, according to scientists in India, there was a higher psychiatric service use in the summer by patients with mood disorders while temperatures were the highest (51). Shiloh et al in Israel concluded that persistent high environmental temperature may be an indicator for psychotic exacerbation in patients with schizophrenia (46). Thus, high temperature and hot climate may be a risk factor that contributes to increased vulnerability and susceptibility for populations at risk of mental disorders.

2. Identifying the vulnerable and susceptible groups to hot weather and heatwaves

In our study, there was a significant difference in gender distribution in which female patients were fewer than male patients. Mental hospitalizations among men were three-fold and they were more at risk of experiencing hot weather compared to those among women. In terms of gender and heat for specific mental diseases, admitted male patients also had higher estimated risks than those for females. The research on gender differences in socioeconomic status and health in Vietnam reported in 2008 that Vietnamese men spent more time outside for occupational activities compared to Vietnamese women (133). This may explain the high relative risks of mental disorders, both all and specific ones, associated with exposures to high temperature or heatwaves at least three days. However, at longer heatwaves, women had the higher risk of mental disorders than men. This may be explained that women’s vulnerability to the impact of extreme heat events is determined by biological and physiological roles (58). Furthermore, the relationship between gender and heat vulnerability varies across situations and countries (58).

The age factor may play a key role in vulnerability and susceptibility for heat-related mental illness in general and for depressive disorders. Patients
in different age groups were studied in terms of their hospital admissions for depressive disorder, and the results showed that the group of 18–40 years old accounted for the highest number of cases. This increases the evidence supporting the assumption that depressive disorders occur much more frequently in those 20 to 40 years of age (21, 23). The study also showed that the elderly had a greater risk of mental disorders in the summer period with a peak of cases in July, and they also had a rising trend with longer exposure to heat extremes. Considering a specific mental disease like Fo-9 (organic mental disorders, including symptomatic illnesses), the elderly also became the most vulnerable and susceptible group to heatwave exposure at the respective strata. The finding was similar to results conducted in Australia on heatwaves-related mental disorders in which the population of 65-74 years of age had the highest risk of mental problems such as dementia (29).

Living environment and conditions may affect health status in general and mental disorders in particular (8, 58). The number of cases for mental disorders among residents in urban regions peaked in the summer time. This may be explained by elevated temperatures and urbanization (111). In consideration of heatwave-associated psychiatric disorders, admissions among residents in rural areas were significantly different from those in urban areas in which relative risks increased especially for ≥ seven consecutive days. In subgroups of specific mental disorders of Fo-9 (organic mental disorders, including symptomatic illnesses), there was an increased trend in hospitalizations with long heatwaves among residents in rural areas. This result was in line with findings from Australia where an increase in rural mental health impacts of climate change was observed (49, 134). It is known that high vulnerability in rural communities can be predicted under more weather variation or extremes (72).

Thus, age, gender, and dwellings may become risk factors contributing to vulnerability and susceptibility for heat-related mental disorders. Furthermore, the elderly may have a low heat tolerance depending on age-related conditions in both the physiological capability to regulate temperature and general health which may induce more increased risk of heat-associated mental illness (76, 135, 136).

3. Research on high temperature and neurotransmitters

The impact of high environmental temperatures on neurotransmitters plays a key role in explaining heat-related mental illness. However, there has been a lack of information on associations between temperature variations and the mechanism of nervous system and neurotransmitters (137). Several studies on biopsychology and bio-physiology might put forth important
knowledge of the association (138-140). This may partly explain our result for when the higher temperatures occurred, there were more admissions for mental disorders to the Hanoi mental hospital.

The autonomic nervous system or sympathetic nervous system (SNS) and the hypothalamic–pituitary–adrenal (HPA) axis comprise two major stress response pathways (18, 23). These systems respond to a novel acute stressor like disaster occurrence and mobilize energy and acuity to meet the demands of a physical stressor (8, 34).

In term of neurobiology, neurotransmitters including serotonin, dopamine, catecholamine, GABA are related to mental health disorders in which serotonin plays an important role in triggering depressive disorders (18). Serotonin is a neurotransmitter known to contribute to the management of circadian rhythms, body temperature and mood (18). Recently, there has been a concern linking the periodicity of depression and hospital admissions to time-pattern variations in neurotransmitters (141). Serotoninergic neurons projecting the suprachiasmatic nucleus of the anterior hypothalamus assist in regulating circadian rhythms such as sleep-wake cycles, body temperature, and the functions of the hypothalamic–pituitary–adrenal (HPA) (23, 141, 142).

Available evidence from research using receptor imaging techniques demonstrated that depression was clearly associated with dysfunction of the 5-HT_{1A} receptors (143). Considerable evidence suggested that the level of serotonin changes in a seasonal manner was related to levels of 5-HT-activity in platelets (141). Seasonal-related risk factors including stress, nutritional habits, tryptophan availability, climatic variables, life events, and comorbidity may impact on 5-HT (144). There were higher platelet 5-HT levels in psychotic patients when compared to non-psychotic depressed patients in the summer, fall and winter (145, 146). Platelet 5-HT concentrations increased in schizophrenic patients with positive symptoms especially in the spring, summer and fall seasons (138, 145, 146). Research in the field of neuro-psycho-biology has illustrated that major depression can be accompanied by activation of the inflammatory response, and release of pyrogenic, pro-inflammatory cytokines causing high body temperatures (23, 141, 142).

Regarding the relationship between high temperature exposure and physiological mechanisms from literature, several experimental studies illustrated there was an association between an increased temperature in the brain and rising temperature in the core body (139). Because heat stress causes an increase in heat production in the brain and/or changed neuronal metabolic activity, this is responsible for impaired neuronal activity and brain
dysfunction (137). Kiyatkin et al demonstrated that the change of external environmental conditions such as alteration to ambient temperature impacted significantly on temperature variation in distinct regions of the brain within 0.5°C to 1.5°C (139). One of the most crucial brain functions influenced by hyperthermia was a change in the blood brain barrier permeability (137). On the other hand, instrumental in heat-related brain dysfunction was a selective disruption of the blood brain barrier to proteins in the areas showing brain edema formation and breakdown of blood brain barrier (137).

Findings from Malberg et al revealed that small variations in ambient temperature (2°C) can trigger a decrease in serotonin concentration and changes in the thermal response to 3,4-methyl dioxymethamphetamine in association to a clear hyperthermic effect at 30°C (147). J.V. Christman et al reported a significant increase in norepinephrine in the preoptic area and DOPEG (dihydroxyphenylglycol) during exercise with hot weather (at ≥ 35°C); this created norepinephrine-induced peripheral heat-dissipating capacity and a rise of catecholamine storage in the preoptic area (138). Furthermore, studies on the relationship between 5-HT and body temperature regulation demonstrated a local application of 5-HT into the preoptic area and anterior hypothalamus which were the important loci for maintaining the body temperature to change the activities of thermo-sensitive neurons (140, 148).

Thus, results from previous research on associations between physiological-psychological mechanisms and high temperatures as well as brain temperature may provide more evidence to explain the assumption that exposure to heat/heat waves may trigger or exacerbate hospital admissions for mental health disorders among populations at risk in the northern region of Vietnam. However, further studies on bio-psychology are needed to confirm the exact mechanism of high temperatures influence on neurotransmitters in triggering mental disorders.

4. Several issues of sociodemographic transitions in Vietnam related to mental health problem in Vietnam

The study analysis showed male patients for mental disorders were three times greater than female patients in which there were more male patients for almost all specific mental disorders except for F30-39, F40-48, and F50-59. According to the literature on mental health problems, the number of women with depression and anxiety was higher than men (18). Hospital admissions for F10-19 among men in the study were much higher than those among women. This may be explained by the high rate of alcohol consumption for
males in Vietnam (92, 126). However, the three-fold difference in admissions for F20-29 among men compared with those among women is unclear.

The high risk of substance abuse and alcohol consumption among Vietnamese men may be causes related to mental health problems (89, 92). In 2010, the prevalence of alcohol disorders among Vietnamese people was 7.9 - 8.7% among men and 0.9% among women in which alcohol dependence was 5.9% and 0.1% for males and females, respectively (107, 126). These risk factors increased the number of deaths and injuries due to traffic accidents and mental disorders associated with substance abuse (107). Nowadays, there are 170,000 people abusing drugs in Vietnam, however, the number may be underestimated because all cases have not been reported officially (149). The majority of cases for drug use has been males (94%) in which more than 70% were younger than 30 years old with heroin consumption (70%) as the common drug (149). Thus, substance abuse consumptions such as alcohol and drugs have been importantly potential risks causing an increase in mental disorders in Vietnam (149). It may be a genuine concern for health managers in Vietnam to develop programs and solutions aimed at helping young population so as to avoid substance abuse because these youth are a major human resource for social and economic growth as well as for the flourishing of Vietnam.

The admissions for mental disorders related to the sequela of brain damage may emerge as delirium and epilepsy. In Vietnam, severe head injuries due to traffic accidents have contributed to the increased mental diseases that include delirium and epilepsy because nearly all severe traffic accidents are associated with alcohol use (18, 127). Vietnam has been one of the nations with a high rate of traffic accidents where every year there are around 9000 deaths and thousands of severe injuries owing to traffic accidents (127). Almost all serious accidents are head injuries and brain damage is a severe sequela to this injury (127). Nowadays, traffic accidents in Vietnam have become a big problem and solutions have been ineffective despite many laws and regulations applied by the government (127).

According to the WHO, the ageing population will trigger increased cases for dementia and Alzheimer’s disease (18). Nowadays, Vietnam has about 95 million people in which there are 30 million in the young population below 19 years old and 10 million elderly over 60 years of age (150). The old population includes 3.2% (3 million) and 6.4% (6 million) among males and females, respectively (150). Thus, in the ageing population in Vietnam, chronic mental diseases such as dementia, Alzheimer’s disease, depression related to cardiovascular disease and cancers has increasingly emerged (150).
Moreover, Vietnam has a young population with over 30% of people under 19 years old (93). According to a recent report, there are 200,000 people with autism and approximately 1 million with mental retardation (128). Therefore, children with mental disorders for autism and mental retardation need to be carefully supervised, especially during weather variations and hot periods. Recent global studies illustrated that children were vulnerable groups to impacts of climate change (8).

Sociodemographic transition in Vietnam showed that there are many potential risks of mental disorders for alcohol or substance abuse, dementia, delirium, mental retardation. Our study also illustrated that there were significant relationships between hot weather, elevated temperatures, heatwave occurrence and mental disorders for F0-9 (organic mental disorders), F10-19 (mental and behavioral disorders due to psychoactive substance use), and F70-79 (mental retardation). In addition, the mental patients among men, and elderly were higher than those among other groups during hot periods. Thus, the evidence supports Vietnamese health specialists and policy makers of the health care service for setting up good preparedness and strategies to prevent and protect population with highly potential risks such as the ageing, the young, patients with mental retardation or autism, and people with substance dependence during heat occurrence.

5. Mental health service in Vietnam on the way to adapt global warming impacts

The result of the hospital-based study in Hanoi, Vietnam for five years (2008-2012) indicated that during the summer seasons or heatwave occurrence, the number of admissions for mental disorders increased especially for the groups of elderly, men, and residents living in rural areas. This indicated that the mental health service in Vietnam needs adequate preparedness to protect populations at risk of mental health problems during hot periods. Nowadays, the mental health service in the provinces do not have sufficient human resources, facilities and equipment to meet the demands for mental health care for 95 million people where around 14 million of them have had mental health problems (82). However, Vietnam has 63 provinces in which each province has two branches of health care service that include health prevention and treatment (96). Moreover, mental health care service is integrated into the health care system in Vietnam, and the health care structure is organized into a hierarchy (88). Hence, the integration of mental health education programs into other health care systems is very important so that the population at risk of heat-related mental illness can be made aware of impacts of heatwaves or extreme heat on their mental health status.
Intervention programs include health educations for improving mental health, perceiving effect of heat on mental health, and preventing stressfulness due to heat. The interventions can be applied to reduce risks related to heat both physical and mental health among the general population and especially the poor health groups.

Encouraging Vietnamese population to use air conditioners during hot weather to mitigate exposure to high temperatures is also essential, particularly for populations in the northern region of Vietnam because in annual summer season the temperature in the north is higher than that in the south. This is a good solution for protecting population at risk (85). However, studies on air conditioner use and human health during the hot time period have not been conducted in Vietnam. In addition, only families with middle and high incomes may be able to set up air-conditioners in their houses. Therefore more research on the relation between using air conditioners and health status during hot weather in Vietnam will be carried out in the future.

Nowadays, there are 60 to 70% of the population with free access to essential psychotropic medicines for some prioritized mental disorders such as schizophrenia, depression, and epilepsy by the community based mental health program (88). In our study, the number of cases for schizophrenia was the highest risk; therefore patients with schizophrenia may be assisted to reduce their costs of mental health treatment. Moreover, managing risk factors related to mental illness, rehabilitation due to mental disease and improving mental health education (knowledge, attitude, practice, behavior) among the population have been targeted and further strengthened (88). Although mental health service in Vietnam was considerably improved over the last decade, further epidemiological and intervention research on mental health services are needed (88, 96).

Problems of socioeconomics and environmental impacts due to climate change can generally affect developments of social and economic growths in Vietnam if good strategies related to policy, human resources, facilities, and equipment to protect populations at risk of mental health are not set up early by Vietnamese government. These play key roles in addressing the challenges and Vietnamese mental health service have been facing in route to adapting and mitigating impacts of global warming on mental health.

6. Vietnamese policy for climate change

Vietnam is a rapidly developing country and with highly exposing natural hazards (7, 12). It has been ranked among the five countries most affected by
climate change because of the rising sea level (13). In addition, one-third of the population falls into the ‘poor’ or ‘near poor’ groups (84). Evidence suggests that the poor population is more vulnerable than others to natural disasters as well as economic and health problems (103). Poor people do not have enough capacity to cope with and adapt to difficult events such as climate change consequences because they have lower access to savings, borrowing, or social protection (84). Moreover, a study in Vietnam indicated that the trend in decreased incomes was influenced by weather variation and extreme weather (103). These may render it incapable for populations especially the poor to adapt to natural disasters.

Furthermore, there are many reasons leading to urbanization, and the impact of climate change is one of them (13). Urbanization due to climate change impacts and urban health problems have become major concerns to providing opportunities for reinforcing local and global environmental sustainability and population health (151). Vietnam has shown an increased trend in urbanization from areas with high impacts due to climate change to cities such as Ho Chi Minh City and Hanoi (99, 100, 102, 103). According to a WHO report, residents in urban areas, particularly the poor population, share some important vulnerabilities in which there were more than 70% of them living in slum-like conditions (152). Therefore, it is crucial to set up good solutions, to effectively manage health problems and socioeconomic issues related to urbanization.

The Vietnamese government has attempted to uncover strategies for adaptation and mitigation aimed at reducing disaster risks for the country through the policy related to climate change such as “National Strategy for Natural Disaster Prevention, Response and Mitigation to 2020” in 2007 and the “National Target Program to Climate Change Response” in 2008 (104). The National strategy has focused on preventing the impacts due to climate change on the population and is aimed at guaranteeing food security, energy security, water security, poverty reduction, gender equality, social security, public health, and better livelihood as well as protecting natural resources in the context of climate change (84, 104). However, these may not have met the demands for the Vietnamese population of approximately 95 million.

The economic growth is very necessary for developing nations like Vietnam, but the sustainability of human health and environment is also crucial. Hence, the balance between economic growth and human health protection has been a major challenge for governments throughout the world particularly in developing countries in sub and tropical regions like Vietnam with the most impacts due to global warming.
Hence, the results of this study contribute to the evidence to support health managers and policy makers in Vietnam in route to establish, maintain, and develop policies, strategies, adaptations, and mitigations related to climate change aimed at protecting populations at risk of heat-related mental illnesses.
Methodological considerations

Limitations and strengths of the study

1. Limitations of the study

In the systematic review, specific research on heat-related mental illness and heat vulnerable populations with characteristics including gender, ages, location and social economics were insufficient. This made it difficult to identify vulnerable and susceptible groups at risk for heatwave exposures and to estimate correlations of heat-related mental illness both all and specific disorders among populations at risk. Moreover, due to a lack of information there was a limitation of the variance in number of cases for mental and behavioral disorders among vulnerable populations.

In the hospital-based study, the five-year database from one psychiatric hospital in northern Vietnam was used to estimate the relationship between elevated temperatures, seasonality, heatwaves and admissions of depression and other mental cases. This may not fully capture all mental disorder patients in Hanoi, especially outpatients.

Regarding the relationship between temperature variations and hospitalizations for depressive disorders, a questionnaire specific to seasonal affective disorder (the criteria defined by the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV)) was not used to diagnose cases and instead all admissions were diagnosed by ICD 10 criteria. Another limitation of the study was the small number of observations for depressive disorders that reduced the power of the statistical tests.

Moreover, it is not possible to generalize the results nationwide because Vietnam has different areas with distinctly specific weather patterns.

A further limitation of the hospital-based research was the lack of information on socioeconomics, occupation status, and marriage status aimed at establishing a model including environment, personal traits, and socioeconomics together with admissions for mental health disorders.

2. Strengths of the study

The study results will contribute to the evidence on relationships between mental disorders and hot weather such as elevated temperature, summer season, and heatwave occurrence. The present study is the first on heat-related mental illness in Vietnam.
Nowadays, there are a limitation of studies on heat-related mental illnesses worldwide, especially in sub and tropical regions. Thus, this research will also provide more information associated with impacts of extreme heat or heatwaves on psychiatric disorders for Asian regions that have suffered from climate change consequences more than other areas of the world.

Implications and future directions

In recent decades, scientists have studied the psychosocial and mental health implications of climate change and have gained attention in the context of disaster recovery from extreme weather events (8, 28). Climate change impacts on mental health through various pathways by imposing natural disasters on human settlements and triggering anxiety-related responses, and thus having implications for neurological health system (8, 28, 79). Direct impacts such as extreme weather events are likely to have immediate effects on the incidence and severity of mental health issues in affected communities as well as significant implications for mental health services (6, 8). Vulnerable communities such as the elderly and children will suffer ongoing disruptions to the social, economic and environmental determinants that promote mental health (8). Climate change may also create emotional distress and anxiety about the future (8). Moreover, exposure to hot weather or heatwaves from consequences of global warming has become a challenge in recent years, especially in subtropical and tropical nations with emerging temperatures (10, 12). However, a few studies on mental disorders related to hot weather and extreme heat were carried out in developed nations such as Australia, Canada, and the United States (8, 29, 68). Thus, further specific research on heat-related neurotransmitters and mechanisms of heat on both physiological and psychological pathways need to be conducted to confirm heat-associated mental illness and to determine the exact mechanism of the relationship. Furthermore, it is necessary to carry out definite studies on the relationship between heat/heatwave exposures and mental and behavioral disorders from both countries of high and low-and-middle- incomes with sufficient information of gender, age groups, settlements, and socioeconomics aimed at identifying and investigating vulnerable and susceptible populations. This will help health managers to set up warning systems for heat-related mental illness and to establish preparedness to prevent mental problems during heatwave occurrence.

In Vietnam, the World Bank reported in 2012 that around 20 percent of the Vietnamese population still lived in extreme poverty and about 27 percent in rural areas (84). In addition, Vietnam is also particularly sensitive to increasing climate hazards including short-lived natural disasters and weather variation (103, 153). In the next 15 years, the poverty eradication in
Vietnam could be slowed by the challenges of climate change including heatwaves, floods, and tropical storms (84). The poverty could be impacted by not only the magnitude of climate change but also demographic and socioeconomic trends (153). By 2030, projected by scenarios, a significant impact on poverty in Vietnam with 400,000 to more than a million people living in extreme poverty would be examined by climate change effects (84). Scientific researchers on climate change and health forecasted that in the future, the impacts of climate change on poverty rates and poor populations in Vietnam will be as much as from climate change itself (153). In particular, the exposure to hotter temperatures and heatwaves can have negative income effects for all socioeconomic groups (103).

According to an analysis of hundreds of baseline scenarios for future economic development in the absence of climate change in Vietnam, the income of unskilled agriculture workers will be the main determinant of the eradication of extreme poverty by 2030, despite the agriculture contributing much more to the socio-economic growth in Vietnam (84, 153). However, workers in agriculture are usually exposed to more hours under sunshine and high temperatures especially in summer season (133). Rising temperatures due to global warming and a long time of exposure to high temperature in the fields may affect their mental health.

Thus, Vietnam, a low-and-middle income country, with over 95 million inhabitants has suffered consequences of climate change (84). This has affected significantly its economic growth as well as epidemic transition of society and urbanization. Like other poor nations worldwide, Vietnam has had insufficient resources for scientific studies on mental health problems related to climate change, and finances for mental health care systems. Moreover, there is discrimination within the community between the healthy population and mental patients. This may make it difficult for early prevention for populations at risk of mental health problems.

Therefore, research on relationships between mental disorders and hot weather and extreme heat exposure, and studies on mitigation and adaptation of global warming consequences are very important in the country. It is difficult to avoid extreme heat occurrence, but we can prevent heat-related mental illnesses with good preparedness strategies to protect the vulnerable populations such as children, elderly, poor people, and the group with poor health in the country.
Conclusion

The findings showed that there was an increased trend in hospital admissions for all and specific psychiatric disorders during heatwave occurrence on the global level. The elderly over 65 years old were more sensitive to heatwave events than other age groups.

Moreover, significant associations between weather variability and depression, as well as other mental disorders supporting increased risks of hospital admissions in elevated temperatures were also found among the population in the northern region of Vietnam during five years (2008 – 2012). Annual seasonal peaks for cases of mental disorders in the summer between June and August were also found. Moreover, there was a high risk of admissions for psychiatric disorders related to heat-waves-exposure at a threshold temperature beyond 35°C, especially during a period of hot temperatures longer than seven consecutive days.

In periods of heatwaves, there were large gender, location and age-group differences with significantly more residents in rural regions and elderly populations above 60 years of age being admitted for psychiatric disorders. Thus, there were significant relations between hot weather and mental disorders in Vietnam, and populations of elderly over sixty years of age, and residents in rural areas were susceptible and vulnerable groups to heatwaves. However, further research nationwide and information on socioeconomics, occupation, and personal traits will be conducted in the future to establish a model with potential risk factors.

Although the study results are formative and may pave a way for future studies in Vietnam, the results can assist doctors of mental health patients in Vietnam in providing more information aimed at exploring the impacts of the exposure to weather patterns, and extreme heat/heatwave on mental health. This also plays a key role to help Vietnamese policy makers and health managers to set up good preparedness and solutions for managing an increased trend in mental disorders and for protecting poor populations and poor health groups when the global warming phenomenon emerges in the future.
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