

Investigating Climate Impacts on Vulnerable Groups: A Case Study of Multiple Sclerosis (MS) Patients in Hong Kong

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Abstract

Raising temperature due to climate change has created profound economic, environmental, and public health challenges, particularly for vulnerable groups such as chronic health patients. This study aims to develop an integrated framework to examine the impacts of rising temperature on vulnerable groups on three critical aspects of health-physical, mental, and social. We conduct a case study of Multiple Sclerosis (MS) patients in Hong Kong. Utilising 53 surveys and 5 in-depth interviews, we found that the physical, mental, and social health of MS patients is adversely affected by increasing temperatures, leading to negatively impacts on daily living, emotional stability, and financial situations for MS patients. Furthermore, the lack of support from the government, power companies, and civil society in alleviating MS symptoms in Hong Kong is evident. This research provides policy recommendations for the HKSAR government, the business sector, and civil society to assist MS patients in managing exacerbating symptoms and physical discomfort during temperature increases, with subsidies on electricity expenses being the most pertinent suggestion for alleviating MS symptoms.

Keywords: climate impacts, vulnerable groups, Multiple Sclerosis patients

1. INTRODUCTION

The urgency to meet ambitious net-zero emission targets before 2050 has driven many national and city governments to introduce new climate policies to steer low-carbon transitions [1]. Social aspects of climate impacts are important but largely overlooked areas in the sustainability literature [1]. Transformation of energy systems, along with other large sociotechnical systems, including

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transport and telecommunications, requires not only technological advancement but also a coevolution of social, cultural and institutional changes that collectively shape energy regimes [2]. The dynamics between vulnerable groups and traditional key stakeholders in energy regimes is not well studied.

Recent literature on climate impacts has increasingly highlighted the importance of paying more sufficient attention to climate impacts on vulnerable groups, underprivileged populations, and remote groups that have limited adaptive capacity and high social vulnerability due to personal, social, and environmental factors [3–5]. The notion of just transitions is an emerging theme in energy studies alongside growing policy interests in this area [6–10].

Multiple sclerosis (MS) patients are one type of vulnerable group. MS patients are especially sensitive to heat. Despite this vulnerability, there have been no prior studies that examined the effects of rising temperatures on the physical, mental, and social well-being of MS patients in Hong Kong. Consequently, there is limited awareness among the public about the challenges MS patients face in coping with increasing temperatures. To address this gap and gain insight into the struggles of MS patients, this research project was developed with specific objectives and research questions.

Globally, the average temperature has increased by 1.36°C in 2023 than in the preindustrial average of the late nineteenth century [11]. The rise in temperature has caused severe human health impacts among vulnerable populations [12,13]. In this context, Hong Kong was chosen as a critical case, since Hong Kong has experienced a significant warming trend over the last century, marked by more frequent and severe extreme heat events. Since 1885, the city has seen an average increase in annual temperatures of 0.13°C per decade, and the increasing rate has increased to 0.24°C per decade between 1991 and 2020 [14]. In 2023, Hong Kong recorded its hottest summer on record from June to August. This gradual warming trend has given rise to certain segments of the population, known as "vulnerable groups at risk from climate change" in Hong Kong. The experience of Hong Kong in responding to climate impacts on vulnerable groups will provide new empirical data to global knowledge from a non-Western context.

Although there is a growing body of literature on climate impacts both globally and locally in Hong Kong, there are at least two major gaps: Firstly, there is a lack of academic research on the impacts of climate risks on vulnerable groups in non-western contexts, particularly in Hong Kong and specifically in relation to specific vulnerable populations such as patients with chronic diseases. Hong Kong is one of the globally leading cities. It shares many other leading cities such as London, New York City, Tokyo, Seoul, and Singapore many changes in urban sustainability transition. The theoretical and empirical contribution of this case study is of scholarly and policy interest beyond Hong Kong and Asia. Secondly, there is a lack of research and understanding of potential policy measures to support MS patients in managing their MS symptoms during periods of high temperature, in order to minimise the impacts on their physical, mental, and social health.

This study therefore aims to identify major types of negative impacts associated with climate risks affecting vulnerable groups, specifically focusing on the implications of rising temperature on MS patients in Hong Kong. We seek to analyse how MS patients are affected by climate risks and aim to provide insights for policy formulation to enhance the resilience of MS patients to cope with climate risks.

To achieve these aims, this study will answer the following research questions:

1. How does rising temperature impact the physical, mental and social health of MS patients in Hong Kong?
2. What coping strategies have MS patients adopted to alleviate their MS symptoms in response to rising temperatures?

3. What policy measures can be proposed and implemented by government, the business sector, and civil society to support MS patients in mitigating the adverse impacts of climate risks associated with rising temperatures?

The remainder of this paper is structured as follows. Section 2 provides a review of relevant theoretical perspectives of climate governance, as well as empirical studies on climate impacts and heat sensitivity of MS patients. A new, multi-dimensional framework is then introduced. Section 3 provides an overview of the study methodology. Section 4 provides the context of the case by discussing the contextual features of the climate risks encountered by vulnerable groups, including MS patients, in Hong Kong. Section 5 presents the main findings. The final section offers some concluding thoughts and policy recommendations.

2. EXPLORING IMPACTS OF CLIMATE RISKS ON VULNERABLE GROUPS: DIVERSE PERSPECTIVES

2.1. Global trends and local impacts of climate change

Climate impacts refer to the hazardous consequences that climatic events pose on various aspects such as ecology, geography, sustainability, poverty, secure livelihoods, land use, and public health [15]. Specifically, climate impacts include increases in temperature and disruptions in rainfall patterns, which are evident in both developing and developed countries. In 2018, the IPCC published a special report titled “Global Warming of 1.5°C” to raise awareness of the potential climate risks associated with acute and irreversible global warming in both the present and future decades.

Recent literature on climate governance has emphasised that climate governance and decision-making processes at national, city, and sub-national levels need to take into account the perspectives of urban vulnerable groups. It is also vital that climate decisions and policies are sensitive to the perceptions, interests and rights of vulnerable populations [16]. In cities where the urban landscape and infrastructure are more conducive to flooding, lower-lying land is likely to be the least expensive. If disaster risk managers do not effectively make use of demographic and census data to better target early warning systems, these populations may also be disadvantaged by not receiving equitable access to timely information.

In the Hong Kong context, the impacts of climate are evident. In addition to the increase in temperature, strengthening of tropical cyclones, alteration of rainfall patterns, and increased extreme cold winter events are major types of climate risks in Hong Kong [17].

Analysis of the annual mean temperature showed that there was an increasing rate of 0.14°C per decade during 1885-2023. The increasing rate was 0.30°C per decade during 1994-2023 [17]. On the other hand, over the last hundred years or so, the numbers of hot nights (days with a minimum temperature of 28°C or above) and very hot days (days with a maximum temperature of 33°C or above) in Hong Kong have increased. Notably, 2021 and 2023 marked the years with the highest number of “Very Hot days” (54 days) since 1884 when Hong Kong Observatory started to record weather data [18]. In terms of rainfall, analysis of the annual rainfall showed that there was an increasing rate of 2.3 mm per year during 1884-2023. The increasing rate of annual mean sea level in Victoria Harbor was 31 mm per decade between 1954 and 2023 [17].

2.2. Five major types of vulnerable groups

Empirical studies on climate impacts suggest that there are at least five main vulnerable groups: outdoor workers, people with low socioeconomic status, residents of coastal and low-lying areas,

the elderly and patients with chronic diseases.

Many outdoor workers, such as those in construction, transportation, and agriculture, are particularly susceptible to heat-related illnesses [19,20]. Heatstroke becomes a significant concern when an individual's body temperature reaches 41°C or higher [21].

Individuals with low socioeconomic status are often the hardest hit by climate risks. The climate crisis disproportionately affects the poor, exacerbating existing economic inequalities [22].

Residents of many low-lying coastal areas are vulnerable to climate risks due to rising sea level, and climate-sensitive physical and ecological characteristics such as flood-prone high population and small-scale economies dependent on marines [23]. IPCC [24] has forecasted that the global mean sea level will continue to rise beyond 2100.

Elderly people with chronic conditions, such as hypertension (high blood pressure), are particularly at risk during periods of elevated temperatures [25]. Those with chronic diseases face increased risks of illness and death due to climate change-related health impacts, including increased exposure to extreme heat, severe weather events, and poor air quality. Such conditions can make individuals more sensitive to health complications and worsening symptoms [26].

2.3. Three main types of negative climate impacts associated with vulnerable groups

Vulnerable groups face three main types of negative impacts due to the climate crisis. Firstly, physical health is threatened as climate change can lead to increased cases of malaria and diarrhea worldwide [22]. Secondly, mental health is at risk, with climate change contributing to emotional distress, anxiety, depression, grief, and suicidal behaviour [27]. Third, social health is affected, as climate change can exacerbate various social risk factors, further affecting psychosocial well-being [27].

2.4. Climate impacts on MS patients

Patients diagnosed with chronic illness, especially patients with Multiple Sclerosis (MS), are among the vulnerable groups under increasing temperature. MS is a chronic inflammatory demyelinating disease of the central nervous system (CNS) that is usually developed among populations aged 20-50 [28]. It is incurable, unpredictable, and varied, as the sites of nerve demyelination of each patient are distinct, which causes disruption of nerve signal transmission to the body that are inconsistent. The factors triggering MS remain unknown. Common symptoms are fatigue, bladder dysfunction, and spasticity [29]. Females are more susceptible to developing MS than males due to the difference in the immune system and the influence of genetic and hormonal factors [30].

The increase in temperature is well known to be a key climate impact that affects MS patients the most. MS patients are well known for their heat sensitivity. According to Plow and Resnik [31], MS patients found it difficult to exercise or participate in outdoor activities, as hot weather will exacerbate their symptoms. They feel lacked energy and motivation under the rising temperature. Furthermore, Induruwa and Constantinescu [32] emphasized that fatigue in MS patients appears to worsen due to hot and humid weather. The most common period of worsening fatigue in MS patients is the second part of the day, and their mobility is limited. They are prone to Uhthoff phenomena, disturbances in neurological functioning when the ambient temperature and the temperature of the core body increase. Short-term and reversible symptoms such as diplopia [33], gait disturbance, and cognitive problems could develop. The gait speed of MS patients may be reduced or result in an imbalanced gait under the hot conditions of their mobility. In addition, MS patients might have cognitive problems, become unable to process

information, and encounter mental fog when the temperature increases. Consequently, they must avoid participating in 'temperature-elevating activities' such as sunbathing to reduce the rate of developing gait disturbance and cognitive problems.

2.5. Main types of supportive measures which can be provided by government, the business sector and civil society

In studies of climate governance, the interest of scholars and policy makers in vulnerable groups stems from a recognition of the problem of inequality. There are a growing body of empirical data that show what and how government, business sector, and civil society should do to support vulnerable groups to cope with climate impacts. The literature suggests that government, the business sector, and civil society can play an important role as follows.

2.5.1 Roles of governments

In addition to subsidies for electricity, the US Department of Veterans Affairs [34] has provided adaptive equipment, such as cooling vests, to MS patients to monitor their body temperature when the ambient temperature increases. MS patients can wear cooling vests to absorb heat and evaporate perspiration when participating in physical activities. Their body temperature around the heart and spinal cord will remain at a safe level. Consequently, exacerbation of MS symptoms can be prevented, which allows MS patients to participate in outdoor activities even when the ambient temperature increases. This reveals that the U.S. government is concerned about the physical and social lives of MS patients under rising temperature.

2.5.2 Roles of business sector

Power companies can help alleviate MS symptoms by providing air conditioning subsidies. Recently, none of the schemes of the two monopolized utilities, China Light & Power, and Hongkong Electric, has provided economic assistance to MS patients to ameliorate their exacerbating MS symptoms when the temperature increases. However, air conditioning is essential to alleviate MS symptoms under increasing temperature. Therefore, suggestion for power companies in Hong Kong will be provided in Section 6.2.

2.5.3 Roles of civil society

Civil society can serve as an assistance to help MS patients receive assistance in relieving their exacerbating MS symptoms when temperatures increase. For example, the Portland Multiple Sclerosis Society (MSSP) non-profit agency in Oregon, USA [35], has operated the Summer Comfort program for MS patients to help relieve the increasing ambient temperature. In 2021, MSSP has cooperated with the Energy Trust of Oregon to assess cooling needs and attempt to provide the most optimal cooling method for MS patients. Furthermore, MSSP had received a bequest from an accomplished artist Leander (Andy) McCormick, who is a MS patient. These events have successfully raised public awareness about the heat sensitivity of MS patients and the provision of new air conditioners for the individual MS patient has exceeded their target of 35%.

2.6. Towards an integrated framework

Based on the literature on climate risks, climate governance and climate impacts on vulnerable groups, we have developed an integrated framework to provide a better conceptualisation of

climate impacts on vulnerable groups, with a focus on chronic illness patients. Our framework has four interrelated building blocks: (i) four main types of climate risks; (ii) five major types of vulnerable groups; (iii) three main types of negative impacts associated with chronic illness patients; and (iv) main types of supportive measures which can be provided by government, the business sector, and civil society.

Our integrated framework explains about how climatic risks including changes in rainfall patterns, intensified tropical cyclones, extreme weather events, and rising temperatures, can impact vulnerable groups. These groups can be distinguished into five categories: residents of coastal and low-lying areas, low socioeconomic status households, outdoor and construction workers, elderly and chronic disease patients.

Focusing on the impacts of climate change on patients with chronic diseases, our integrated framework highlights rising temperatures as the most important climate risks affecting the physical, mental, and social health of patients with chronic diseases. These aspects are highlighted in blue boxes in Figure 1.

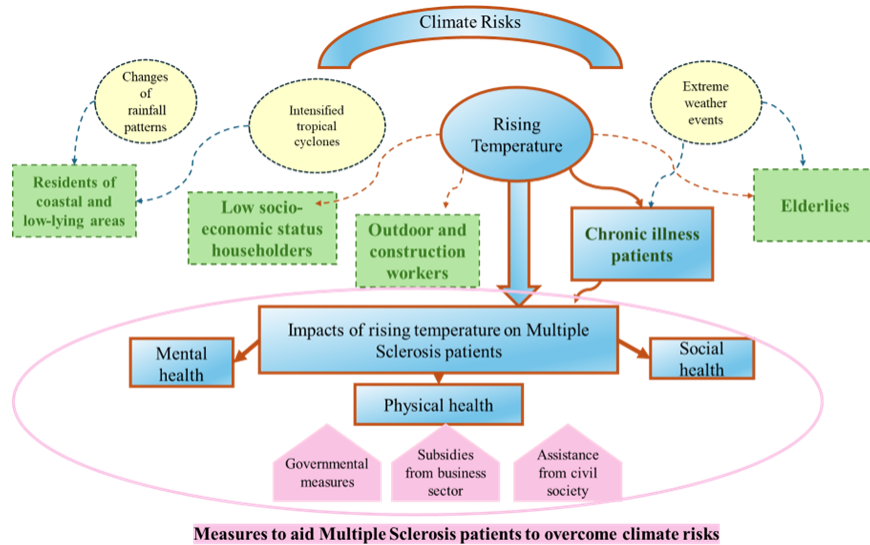


Figure 1: An integrated framework of climate impacts on vulnerable groups

3. METHODOLOGY

This study adopts a mixed-method, case-study approach to provide a better understanding of the impacts of climate change on MS patients in Hong Kong. Our mixed method approach collected quantitative and qualitative data from four primary sources: desktop research, 53 surveys conducted with MS patients in Hong Kong, and five semi-structured in-depth interviews and direct participation.

3.1. Desktop research

Our desktop research drew on a variety of sources, including academic publications, government documents, and the mass and social media. International and local reports have been reviewed. Intergovernmental reports, such as the IPCC Comprehensive Assessment Report, provided rich

information on climate impacts. Empirical data on climate impacts in Hong Kong were obtained from the official website of the Hong Kong Observatory to ensure the credibility of the data. Online search engines, including Google Scholar, OneSearch, the HKBU library, and JSTOR are the dominant means of acquiring information. In addition, impacts of climate risks on vulnerable groups in Hong Kong are derived by integrating secondary data from multiple sources, such as government documents, newspapers, 14 international academic journals, and research reports.

3.2. Surveys

A survey was distributed to a group of 214 MS patients through the social media platform Facebook in June 2021. By the end of June 2021, 53 were completed and used for analysis in this study. Since there are approximately 700 MS patients in Hong Kong, the survey, to our knowledge, is the first of its kind to collect primary data from a significant proportion of approximately 7.57% of MS patients in Hong Kong, revealing their living experiences under increasing temperature. This survey thus provided a rare and valuable primary dataset from the nonwestern context that has been vastly underrepresented in the literature.

The survey focused on three themes of questions: the impacts of rising temperature in recent years on their physical, mental and social health, respectively. The quantitative research method enables subjective feelings of MS patients about their exacerbation of MS syndrome under rising temperature to be counted as numerical data and generalized into a phenomenon.

In addition, 5 household electricity bills were acquired from 2 out of 4 MS patients interviewed. The provided quantitative data on electricity consumption would supplement the quantitative survey data and qualitative interview data. 2 interviewees who did not provide household electricity bills due to privacy concerns. The energy data include bimonthly household electricity consumption of MS patients, enabling us to analyze their usage of electricity appliances to relieve potential MS symptoms triggered by increasing temperature. The energy data will be compared to that in the same period in previous years. Afterwards, the correlation of the application of air conditioning to ameliorate MS symptoms under increasing temperature could be generalized in the quantitative research method.

3.3. Interviews

Five semi-structured, in-depth interviews were conducted with three different stakeholder groups, medical professionals, civil society, and MS patients in June and July 2021. The interviews were conducted to collect qualitative and in-depth data to enrich our understanding of the influence of increasing temperature on the physical, mental, and social health of MS patients from the perspectives of these different stakeholder groups. These qualitative interview data are crucial in supplementing our quantitative survey data.

Table 1 provides an overview of the interviewees. In order to keep our interviewees anonymous, this study indicates the interviews by number. Informed consent forms are signed by interviewees to clarify the purpose, benefits, risks, and confidentiality of this study. The first two letters indicate the location and the two digits indicate the interview numbers, followed by the year of interviews. The interview formats included face-to-face, telephone, and Zoom interviews. The interviewees include a nurse officer from a public hospital, a former director of an NGO of MS patients (who is also an MS patient), and three MS patients who represent MS patients with long, medium, and short MS medical history. The nursing officer has extensive experience in taking care of MS patients, serving MS patients in the public health sector in Hong Kong for more than six years. An

interview was conducted in person, one on the phone, and three through online zoom meetings. The duration of each interview ranged from 15 to 30 minutes.

Interview questions for MS patients were designed along three main themes, including asking for their medical history, the influence of Uhthoff’s phenomenon on physical, mental, and social health, and the expectation of support from civil society.

3.4. Direct participation

Direct participation of the first author in a public seminar titled “Combined Effects of Western and Chinese Medicines in Treating MS patients” in October 2020 was used as a data collection method to gather expert views on the impacts of rising temperatures on MS patients. The first author attended the seminar and asked questions as a seminar participant to collect expert views from two expert panelists. The first panelist was a western medical practitioner who was the head of a neuroscience Unit of a public hospital, and an honorary associate professor of a medical school. The second panelist was a Chinese medical practitioner who is a head of an integrative medical centre of a faculty of medicine of a medical school in Hong Kong. The questions asked by the first author were informed by desktop research. Expert views from the two panelists on Uhthoff’s phenomenon encountered by MS patients are collected for our data analysis.



Figure 2: The public seminar on “Combined Effects of Western and Chinese Medicines in Treating MS patients” in October 2020

Table 1: An overview of interviewees

Code	Background of Interviewee	Date of Interview	Format of Interview
Interview 1	A nursing officer from a division of Neurology in a public hospital in Hong Kong	20th July 2021	Face-to-face
Interview 2	An MS Patient (Patient D) and a representative of an NGO (a former director of the Hong Kong Neuro-Muscular Disease Association Limited)	25th June 2021	Zoom
Interview 3	Patient A, an MS patient (Diagnosis with MS: 2002 - 2021, 19 years)	24th June 2021	Phone
Interview 4	Patient B, an MS Patient (Diagnosis with MS: 2014-2021, 7 years)	25th June 2021	Zoom
Interview 5	Patient C, an MS Patient (Diagnosis with MS: 2019-2021, 2 years)	25th June 2021	Zoom

4. CASE CONTEXT: CLIMATE IMPACTS ON VULNERABLE GROUPS AND THE MS PATIENTS IN HONG KONG

This section provides the case context by reviewing the climate risks faced by vulnerable groups, including MS patients, in Hong Kong. Hong Kong is an international metropolis with a population of 7.54 million and a GDP of HK\$2,982 billion (2023) [36]. Located in the southern part of the Pearl River Delta (PRD), it is a coastal city that has experienced rising temperatures and other climate risks in recent decades, including tropical cyclones, changing rainfall patterns and cold waves [17].

Drawing from empirical studies on climate impacts in the context of Hong Kong, it is evident that there are at least five distinct vulnerable groups within the local population. These groups include outdoor and construction workers, people with low socioeconomic status, residents of coastal and low-lying areas, elderly people, and patients with chronic diseases.

4.1. Outdoor workers and construction workers

Outdoor workers and construction workers who work in non-air-conditioned environment may face a serious threat from rising temperatures. Among those at risk are construction workers and street cleaners, who are exposed to adverse health effects under extreme heat conditions. Heatstroke becomes a concern when the body temperature of an individual reaches 41°C or above [21]. Construction workers are particularly vulnerable to heat stress due to the elevated temperatures often present at construction sites compared to the readings of the Hong Kong Observatory [37]. Factors contributing to this include direct sunlight exposure on roofs, inadequate ventilation, and the absence of air conditioning on site. Consequently, the abnormal rise in ambient temperatures in Hong Kong poses significant health risks to these workers.

Street cleaners represent another vulnerable group, as they are bound by the working guidelines outlined by the Department of Food and Environmental Hygiene (FEHD). According to expected performance standards, FEHD requires workers to sweep the streets and empty the trash cans 4-8 times a day. The target set for 2020 was 95%, which means that street cleaners were expected to meet this standard on at least 347 days. In 2020, street cleaners achieved a 100% compliance rate with this target [38]. This highlights the reality that these workers must persevere in their duties regardless of weather conditions until the target is met. However, this places them at risk of heatstroke when working on very hot days.

4.2. Low socio-economic status householders

Low socioeconomic status households, in particular subdivided flat residents, are vulnerable to climate impacts. The general concerns of this vulnerable group include increased expenditure, safety issues, and mental health of subdivided flat residents are the main concerns. Subdivided apartments also tend to have poorer air ventilation, leading residents to respond to air conditioning during 'very hot days'. Consequently, rising temperatures can result in increased household expenditure on air conditioning, making electricity bills unaffordable for low-income groups [39].

When it comes to the mental health of subdivided flat residents, various factors such as socioeconomic status, social exclusion, poverty, and living conditions can significantly impact their well-being [40]. Research has shown that high temperatures can trigger increased aggression and impulsivity in individuals [41]. As temperatures in Hong Kong continue to rise due to global warming, residents of subdivided flats may face additional challenges, exacerbating their mental distress.

4.3. Residents of coastal and low-lying areas

warming. The mean sea level in Victoria Harbour has increased by 14 centimeters between 1954 and 2009, primarily due to the thermal expansion of the global sea volume and the loss of land ice caused by global warming [42].

Tai O serves as an example of a low-lying area in Hong Kong that is particularly vulnerable to rising sea level, flooding, and storm surges triggered by tropical cyclones. The residents of Tai O experienced the wrath of Typhoon Hagupit in September 2008, marking one of the most severe typhoons encountered in recent years. Hong Kong Observatory [43] issued Tropical Cyclone Warning Signal No. 8 and Amber Rainstorm Warning Signal as Hagupit approached Hong Kong in September 2008. The combination of strong winds, storms, and heavy rainfall compromised the living conditions of Tai O residents. Hagupit brought about a storm surge, causing water levels to rise to 3.7 meters high. The electricity supply in Tai O was disrupted, impacting nearly 200 households [42]. Furniture and electronic appliances, such as refrigerators, were damaged by the floods, necessitating significant expenditures for repair.

Furthermore, Heng Fa Chuen, a middle-income private residential housing estate comprising 6,028 households [44], is another notable location vulnerable to climate risks associated with typhoons. The coastal flooding and massive waves from Super Typhoon Mangkhut in 2018 posed a significant threat to Heng Fa Chuen [45]. Residents experienced buildings swaying and beds shaking when Hurricane Signal No. 10 was raised [46]. The underground car park at Heng Fa Chuen was inundated during the typhoon, with seawater flooding the area due to storm surges associated with Super Typhoon Hato in 2016. This unfortunate event resulted in extensive damage to numerous private vehicles [47].

4.4. Elderlies

Extreme low temperatures can significantly increase the mortality risk for the elderly. For instance, in January 2021, 11 Hong Kong citizens lost their lives due to the winter monsoon affecting the coast of Guangdong on the 9th and 10th of January. The minimum temperature during these two days was 7.7°C, and the youngest victim was 54 years old [48], highlighting the increased vulnerability of the elderly to extreme cold weather.

However, extreme high temperatures can cause heat-related illnesses such as heat exhaustion and heat stroke. In Hong Kong, 29.5% of the population aged 15 or above have hypertension, with 57.4% of them falling in the 65-84 age group [49], indicating a significant proportion of the population at risk. Common symptoms of high blood pressure include headaches, fatigue, dizziness, and even visual disturbances [25]. Therefore, the projected abnormal increase in ambient temperatures in Hong Kong poses a threat to people with hypertension.

4.5. Patients with chronic illness

Extreme temperatures can lead to an increase in hospital admissions and mortality rates. In the context of cold temperatures, patients are particularly susceptible to prolonged cold effects (lasting less than three weeks). Patients with "non-accidental, cardiovascular, respiratory" diseases and cancer are at higher risk of mortality compared to other groups of patients under cold weather conditions [40].

4.6. MS patients in Hong Kong

Patients with chronic illnesses, including those with Multiple Sclerosis (MS), are among the vulnerable groups impacted by climate change. According to a nursing officer from a division of neurology in a public hospital in Hong Kong, there are approximately 700 MS patients receiving medical services in public hospitals in Hong Kong in 2021 (Interview 1). To the best knowledge of the authors, the exact number of MS patients in private hospitals is not publicly available, rendering the total number of MS patients unknown. Furthermore, there is a dearth of scientific research on the Uhthoff's phenomenon and the exacerbation of MS symptoms in response to rising temperatures experienced by MS patients in Hong Kong. Despite conducting a thorough desktop research using keywords such as "Multiple Sclerosis," "temperature," "Uhthoff's phenomenon," and "Hong Kong," no relevant studies were found on this specific topic.

5. FINDINGS AND DISCUSSION

Our case study of MS patients in Hong Kong found that climate risks, particularly rising temperatures, can have detrimental effects on patients with chronic diseases. The following section will discuss the results of the survey collected from 53 patients with Multiple Sclerosis (MS) regarding the implications of increasing temperatures on their physical, mental, and social well-being.

5.1. Magnitudes of negative impacts of rising temperatures on MS patients

A significant majority of the MS patients surveyed have reported adverse effects from increasing temperatures in recent years. 89% of the respondents indicated that they felt unwell due to the rising temperatures in Hong Kong. This observation is consistent with the heat sensitivity often observed in MS patients, as evidenced in the existing literature. Both Western and Chinese medical professionals have shared their expert opinions on this issue. Neurologist Dr. Lau has affirmed that elevated temperatures can worsen existing MS symptoms. Furthermore, Chinese medical practitioner Dr. AU has suggested that rising ambient temperatures may exacerbate the "Huo Qi" (internal heat leading to inflammation of body tissue) in MS patients. Therefore, it is plausible to anticipate a deterioration in MS symptoms with increasing temperatures.

5.2. Noticeable decline in physical health among MS patients due to rising temperatures

The survey revealed that MS patients reported experiencing six types of physical discomfort, with sensations of feeling "powerless, difficulty in walking" and "abnormal fatigue and exhaustion" being the most prevalent when temperatures increase (Figure 3). These symptoms can result in slower walking pace and even potential falls when outdoors. Furthermore, 11% of the respondents noted experiencing "numbness of limb", "imbalance gait" and "dizziness with blurred vision" respectively, while 6% reported "difficulty in breathing" as temperatures rose.

To shed light on the challenges facing MS patients, a nursing officer from the Division of Neurology explained that the nerves of MS patients become more sensitive when exposed to high or cold temperatures as follows.

These patients sometimes feel their nerves are too contracted to move barely. The temperature will make the nerves more sensitive, triggering a cascade of reactions in their attached muscle groups (Interview 1).

This heightened sensitivity can trigger the contraction of the corresponding muscle groups, leading to abnormal limb sensations and difficulties in muscle control. Consequently, the exacerbation of MS symptoms may occur due to the impact on affected nerves and muscles, a phenomenon known as "Uhthoff's phenomenon." These empirical data in Hong Kong confirm the literature that has documented that MS patients are particularly susceptible to neurological disturbances when ambient and core body temperatures increase.

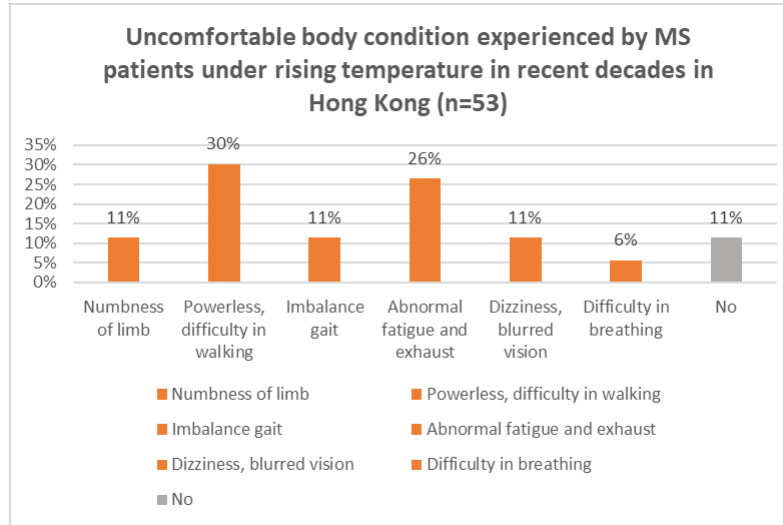


Figure 3: Uncomfortable body conditions of MS patients under rising temperature in percentage

5.3. Impact of rising temperatures on mental health of MS patients

The increase in temperature can cause significant mental health challenges among patients with MS. A majority, 64%, of the 53 respondents reported experiencing various mental health issues during temperature increases (Figure 4). Specifically, 26% expressed concern about the deterioration of their MS medical condition in response to rising temperatures. Many respondents feel anxious about the potential worsening of their existing MS symptoms. Nursing Officer Au highlighted that some MS patients may even fear a relapse of multiple sclerosis due to temperature fluctuations (Interview 1).

Furthermore, 17% worry about the exacerbation of MS symptoms under increasing temperatures that affect their work and daily lives, while 4% of the respondents experience moodiness and irritability when temperatures rise. In an interview, MS Patient D shared feelings of irritability and worry when temperatures increase (Interview 4). At times, he becomes agitated and inadvertently vents his frustration towards family members. The discomfort caused by the rising temperatures has made him more impatient, with throwing objects becoming a manifestation of his frustration triggered by the heat. Consequently, the stability of family relationships may be compromised. In addition, increasing temperatures can induce feelings of depression and desperation among MS patients, with 2% of the respondents reporting suicidal thoughts when temperatures increase. This aligns with Cianconi, Betrò [50], which suggests that rising temperatures could have an immediate impact on mental health. Therefore, the connection between mental health problems in MS patients and increased ambient temperatures should not be underestimated.

Lastly, 15% of respondents are concerned about the continuation of abnormal climate conditions

in Hong Kong and globally in the future. According to the results of the survey, 62.5% of these respondents are concerned about the continued rise in ambient temperatures. One respondent emphasized the challenges posed by the lack of favorable ventilation due to the alignment of high-rise buildings in Hong Kong, causing a feeling of being "suffocated." This phenomenon, known as the "wall effect" as mentioned in [51], occurs when air flow is hindered by high-rise buildings along the coastline, resulting in poor air ventilation in urban areas. Consequently, the combined impact of the "wall effect" of high-rise buildings and rising temperatures in Hong Kong can trigger anxiety among MS patients about the potential exacerbation of MS symptoms.

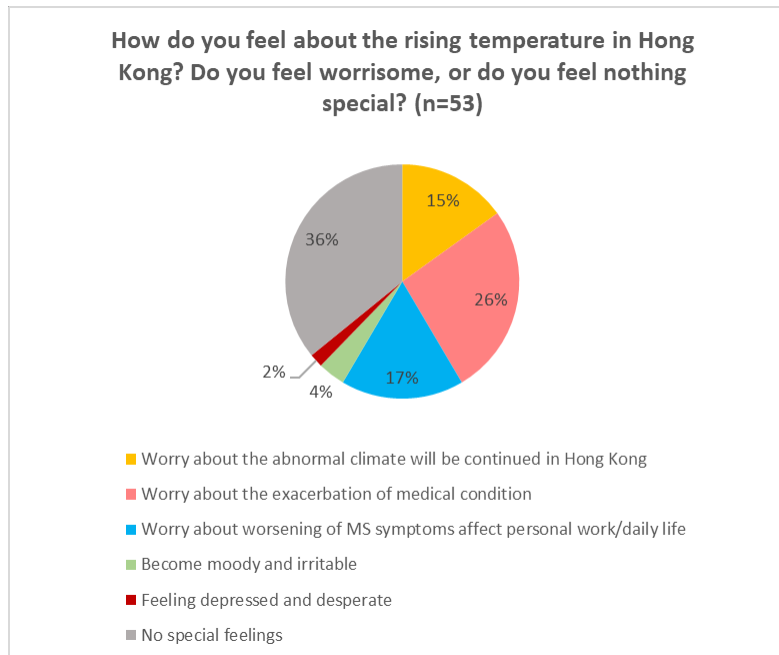


Figure 4: Mental health problem of MS patients on the rising temperature in Hong Kong

5.4. Deterioration of social health among MS patients in response to rising temperatures

MS patients interact with others in various social settings, including family, neighborhood, school, and public spaces. However, the social lives and social health of MS patients have been adversely affected by the issuance of hot weather warnings and increasing temperatures in recent times, manifesting in two key dimensions.

Firstly, the social lives and interactions of MS patients in different settings have been constrained by rising temperatures. For example, 43% of the respondents refrain from participating in outdoor leisure activities. In particular, MS Patient B mentioned that he avoided outdoor activities, such as sports and social gatherings with friends due to the physical challenges exacerbated by increasing ambient temperatures. This highlights his sensitivity to temperature as a significant concern before engaging in outdoor recreation activities to prevent further deterioration of his physical condition. Additionally, as shown in Figure 5, 17% of respondents, including MS Patient C, have curtailed their participation in outdoor leisure activities (Interview 2). She views activities like jogging in high temperatures as a "luxury" her body cannot afford, leading her to limit outdoor excursions

such as quick trips to the market for essential items.

I used to walk so fast, but I started walking slowly for these two years. I try to avoid outdoor activities, usually I spend the afternoon in the mall and return home at night, when I stay at my apartment, I will continue to turn on the air conditioner. I try to avoid sports such as mountain climbing (Interview 2).

Secondly, the intrinsic social health of MS patients is affected by increasing temperatures. 15% of the respondents opt out of outdoor activities with high physical demands. For example, MS Patient D avoids activities such as jogging and taking his children to theme parks due to the increased physical exertion required compared to indoor family activities like leisurely walks in shopping malls (Interview 4). His desire to alleviate concerns about his physical condition among family members reveals that MS patients may compromise their intrinsic social health by limiting their social engagements when temperatures rise.

The above analysis indicates that barriers to the formation of friendships and the maintenance of family relationships through outdoor activities in hot weather are evident in the social lives of MS patients. They raised concerns about how their medical symptoms can worsen and impact their companions, leading them to withdraw from many outdoor activities. This suggests that MS patients miss out on opportunities to alleviate anxiety and regain focus by participating in outdoor leisure activities, which can affect their mental health over time [52].

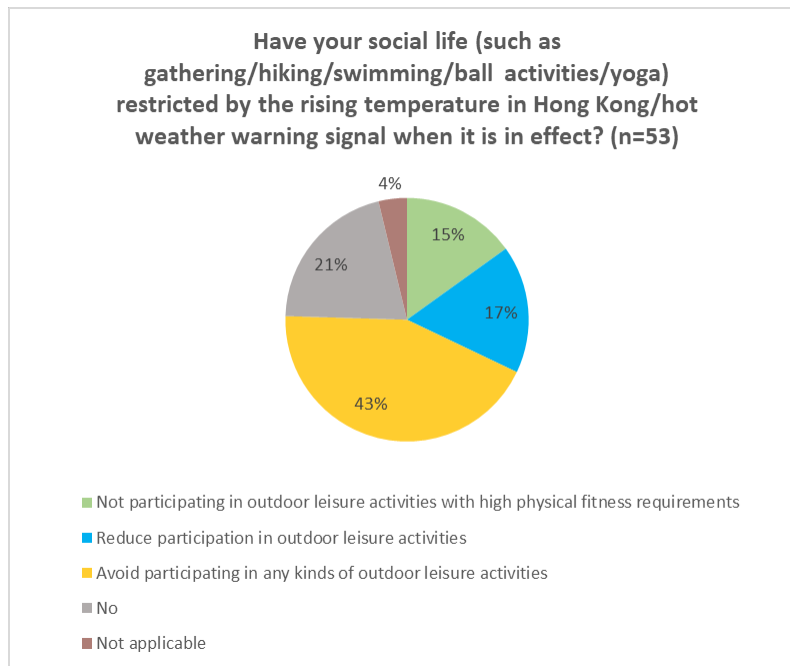


Figure 5: Degrading of social life of MS patients when temperature increase

5.5. Negative social health impacts on daily lives of MS patients due to temperature increases

The exacerbation of MS symptoms triggered by rising ambient temperatures can lead to emotional instability, affecting the daily lives and financial situations of MS patients.

In terms of emotional stability, 34% of respondents experience feelings of sadness, irritability, or depression when temperatures rise, as they worry about the potential worsening of their MS symptoms in the future (Figure 6). For instance, MS Patient A has expressed concerns about the impact of rising temperatures on her MS symptoms, viewing the temperature increase as unavoidable and beyond the control of ordinary citizens in Hong Kong (Interview 3). Her passive attitude towards the effects of temperature rise on her condition reflects a sense of desperation, highlighting the threat that rising temperatures pose to the mental health of MS patients.

Regarding daily life, 30% of the respondents report feeling fatigued and lethargic when their MS symptoms deteriorate under increasing temperatures, significantly affecting their daily routines. MS Patient D shared his experience of increased fatigue with rising ambient temperatures, noting that he has been experiencing this abnormal fatigue as early as April, earlier than in previous years (Interview 4). This suggests that rising temperatures have prolonged the duration of abnormal fatigue experienced by MS patients. In addition, muscle contractions leading to immobility are common MS symptoms exacerbated by rising temperatures. Twenty-five percent of the respondents mentioned that they faced restrictions in their daily activities due to immobility caused by heat. MS Patient A described how her legs feel weak and paralyzed when temperatures increase, making walking challenging (Interview 3). The nursing officer interviewed stressed that immobility among MS patients can occur suddenly at high ambient temperatures, posing risks to their safety. For instance, MS patients may experience sudden immobility even while crossing the road, a concern also acknowledged by MS Patient B (Interview 5). Therefore, MS patients are vulnerable to unpredictable dangers in their daily lives when temperatures rise.

I feel tired more and more easily, and this symptom becomes more common than before. It is not about some part of my body, I feel my whole body is getting tired, which even leads to a headache. Since the weather is getting hotter than ever, it makes me feel more uncomfortable (Interview 4).

Regarding medical, transportation, and electricity expenses, 13% of the respondents reported an increase in these costs as they implemented various measures to manage the discomfort of their MS symptoms under increasing temperatures. For example, two respondents mentioned an increase in medical expenses due to more frequent appointments during hot weather. In addition, two respondents relied more on personalized point-to-point transportation services, such as taxis, when their MS symptoms worsened in high temperatures.

5.6. Measures to prevent/relieve MS symptoms under rising temperature

An important aspect to consider is the increase in electricity expenses for MS patients as temperatures increase, which will be discussed in the following section.

Most of the MS patients surveyed rely on cooling electrical appliances, particularly air conditioners and fans, to alleviate or prevent the worsening of MS symptoms and discomfort in response to increased ambient temperatures (Figure 7). 53% opt to remain in places equipped with fans and air conditioning, highlighting the crucial role of heat dissipation devices in helping them manage and prevent the exacerbation of MS symptoms. All MS patients interviewed stress the essential nature of air conditioning and fans in alleviating their discomfort from MS symptoms. For instance, MS Patient A emphasizes that air conditioning is the "only" effective strategy to mitigate the aggravation of her symptoms in response to rising temperatures and the humid climate in Hong Kong (Interview 3). Her sentiments are supported by Dr. Alexander YL Lau, who notes that existing or relieved MS symptoms can worsen when temperatures and humidity levels rise. In addition, MS symptoms can escalate rapidly, such as during hospital visits when patients are exposed to high temperatures. Dr. Lau recommends that MS patients stay indoors

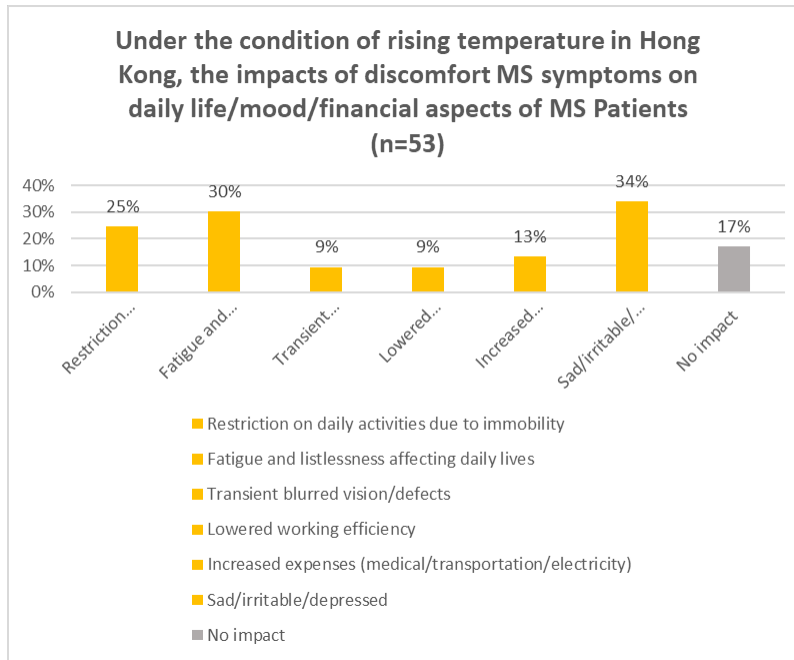


Figure 6: Impacts of discomfort MS symptoms induced by rising temperature on daily life/mood/financial aspect of MS patients

with air conditioning to alleviate the exacerbation of their symptoms. MS Patient C has followed this advice by seeking refuge in shopping malls to alleviate the worsening symptoms of MS and prevent further exacerbation when temperatures rise.

To investigate the potential benefits of using air conditioning to alleviate the exacerbation of MS symptoms in response to rising temperatures, an examination of the electricity bills of two interviewed MS patients was conducted. First, it is important to establish the average residential energy consumption of Hong Kong citizens. According to the Legislative Council [53], a "typical three-member household" consumes around 275 kWh per month and incurs charges of either \$230 from HKE or \$320 from CLP.

In Figure 8, we observe the electricity bill of interviewee MS Patient A for the period from April 4th 2021 to June 3rd 2021 (Interview 3). As a one-member household, her bimonthly residential energy consumption is 610 kWh, which is equivalent to 305 kWh per month. Surprisingly, her monthly residential energy consumption exceeds that of a typical three-member household. Furthermore, she has consistently consumed more residential energy in August 2019 and 2020 compared to other months. These patterns suggest that she may have been using more energy for heat dissipation electronics to alleviate the exacerbation of her MS symptoms during the summer months.

Figure 9 shows the electricity bill of interviewee MS Patient D for the period from 7th May 2021 to 7th July 2021 (Interview 2). Coming from a two-member household, her bimonthly residential energy consumption is 757 kWh, indicating a consumption rate of 378.5 kWh per month. Surprisingly, her monthly residential energy usage exceeds that of a three-member household by 103.5 kWh. It is noteworthy that she consistently consumed more residential energy in July and September from 2019 to 2021 compared to other months. Furthermore, her average daily energy consumption in July has shown a steady increase from 8 kWh in 2019 to 10 kWh

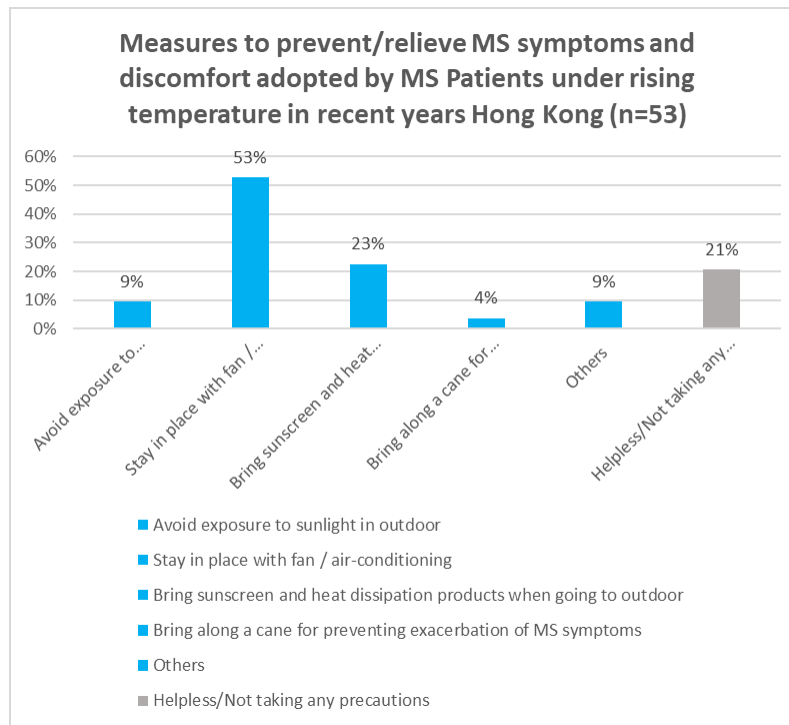


Figure 7: Measures adopted by MS patients to prevent/relieve MS symptoms and discomfort under rising temperature

in 2020 and 12 kWh in 2021, suggesting a growing trend in energy use during the summer months. This pattern indicates a potential reliance on heat dissipation electronics at her residence to alleviate the exacerbation of her MS symptoms in response to increasing ambient temperatures.

The increase in energy consumption poses a financial burden on interviewee MS Patient D, as she is required to pay more for energy charges than a "typical three-member household" by \$11.5 per month [(\$663/2) - \$320] (Interview 2). Consequently, a significant disparity in energy costs between the homes of MS patients and typical homes may become more pronounced over the long term.

The nursing officer has recommended swimming as a beneficial activity for MS patients to alleviate their worsening symptoms in response to rising temperatures. She emphasized that the temperature of the swimming pools in the room allows MS patients to effectively regulate their body temperature as ambient temperatures increase (Interview 1). This controlled environment helps prevent internal heat acceleration in MS patients, as noted by Chinese medicine practitioner Dr. Au, thereby reducing inflammation in body tissues and potentially mitigating the exacerbation of MS symptoms.

Moreover, research indicates that 23% of respondents plan to "bring sunscreen and heat dissipation products when going outdoors," as depicted in Figure 7. For instance, they carry items such as portable fans, hats, towels, and parasols when venturing outside. This trend demonstrates that MS patients are becoming more aware of the potential impact of rising temperatures on their MS symptoms. By taking proactive measures to maintain a stable body temperature and prevent the worsening of their condition, MS patients are showing a growing understanding of self-care strategies to manage their MS effectively.

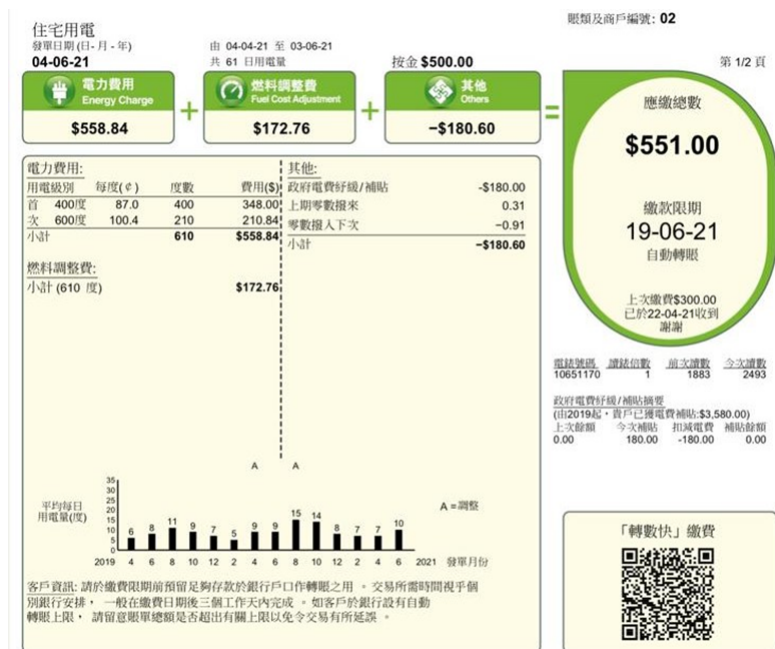


Figure 8: Electricity bill of interviewee MS Patient A

5.7. An overview of varying climate impacts on MS patients with different medical history

A progressive trend of deteriorating body sensations under increasing temperatures was identified among the 53 surveyed MS patients. Interestingly, a direct relationship between the duration of an individual’s MS medical history and the intensity of negative body sensations was observed. The respondents were segmented into three distinct categories based on their medical history: “New patients” refer to MS patients who have been diagnosed with MS for 10 years or less. “Moderate-history patients” refers to patients who have been diagnosed with MS between 11 and 20 years of age. “Long-history patients” refers to patients who have been diagnosed with MS for more than 20 years.

Among the 26 respondents in the "New patients" group, 62% reported experiencing different body sensations in the summer of 2021 compared to when they were first diagnosed with MS. Of this group, 31% observed a deterioration in body strength, leading to feelings of fatigue and reduced productivity. Additionally, 15% experienced limb weakness, and 8% reported numbness, indicating significant neurological disturbances triggered by temperature increases, which aligns with the findings from [54].

In an interview, MS Patient B highlighted the compounding effects of humidity and rising temperatures. He described humidity as a "multiplier" that intensifies the impact of heat on MS patients, causing discomfort and exacerbating symptoms (Interview 4). This aligns with the concept put forth by Havenith [55] about the challenges of heat dissipation under humid conditions. The inability to release excess heat in high humidity environments can lead to the aggravation of MS symptoms.

Of the 21 respondents from the "Moderate-history patients group", 86% reported changes in body sensations between the 2021 summer and their initial MS diagnosis. Most notably, 67% experienced a decline in body strength, 14% had weakened limbs, and 5% suffered from blurred

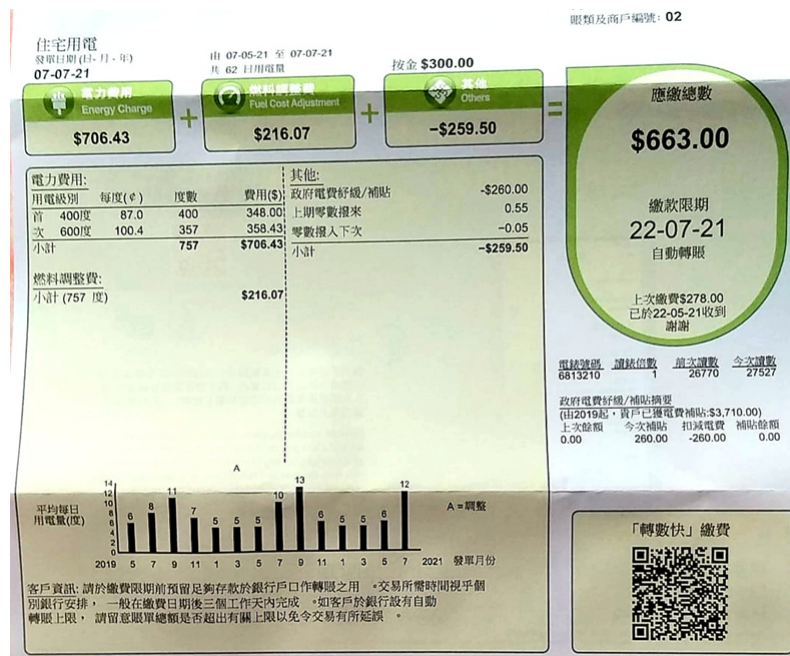


Figure 9: Electricity bill of interviewee MS Patient D

vision under rising temperatures.

According to interviewee MS Patient A, her limbs become “powerless” under rising temperature which makes it hard for her to walk. Further, she has suffered from “blurred vision” and “shaking of eyeball” when ambient temperature increases (Interview 3). The nursing officer explained the exacerbation of MS symptoms under rising temperature is due to neurological sensitivity. The peripheral muscle groups of sensitive nerves will react immediately. For example, “contraction and tightening of muscles” are results of heat sensitivity of nerves which exacerbates MS symptoms like “limbs become powerless” and “difficulty in walking” (Interview 1). These highlight that the neurological disturbance caused by rising temperature on the symptoms of MS patients could vary depending on the affected nerves.

Comparing the impacts on “New patients” and “Moderate-history patients”, there was a notable increase in the percentage of individuals experiencing altered body sensations due to rising temperatures. According to the nursing officer, this shift suggests a heightened nerve sensitivity in MS patients over the years, potentially worsening initial symptoms like limb numbness (Interview 1).

Regarding the impacts of rising temperature on “Long-history patients”, 100% of 6 respondents report that they have a different body feeling between 2021 summer when comparing to the year they first diagnosed with MS. They noted that there was a significant deterioration of body strength when ambient temperature increased. According to Dr. Alexander YL Lau, the relieved MS symptoms could be exacerbated again due to neurological disturbance caused by rising ambient temperature.

Across the three categories of patients, a progressive trend was observed in differences in body sensations between the summer of 2021 and the year of diagnosis of MS. This trend suggests that as the duration of MS diagnosis increases, the impact of rising temperatures on MS symptoms becomes more pronounced. Although “New patients” may initially be less aware of these effects,

the influence of climate on MS symptoms becomes more prevalent with longer medical histories.

Based on empirical evidence, this study has developed Figure 10 to provide a schematic representation of the negative impacts of rising temperatures on MS patients. Our empirical analysis highlights the negative influence of rising temperatures on the physical, mental, and social well-being of MS patients, affecting daily routines, emotional stability, and financial resources. Our findings are in line with the results of [56–58] in the US.

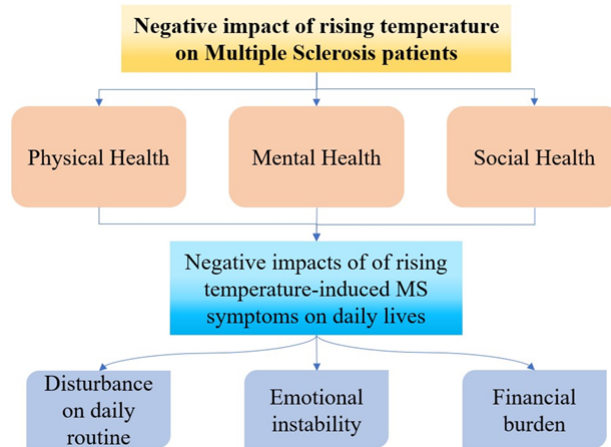


Figure 10: An overview of negative impacts of rising temperature on MS patients

5.8. Insufficiency of governmental regulations, business sector and civil society

5.8.1 Insufficient support of governmental regulations

According to the Labour and Welfare Bureau of Hong Kong government, MS patients are categorized as suffering from “Physical disability” which is “temporary”. Therefore, MS patients are not eligible to apply for the “Registration Card for People with Disabilities”.

MS patients are not eligible to apply for “Disability Allowance” provided by the publication of the Social Welfare Department (SWD) which is prepared for “severely disabled” Hong Kong citizens consequently. Hence, costs for transportation of MS patients can be increased when their MS symptoms are aggravated by rising temperature without the subsidies provided by SWD. They have to spend more money traveling to their destination once their MS symptoms are suddenly aggravated in a hot outdoor environment.

5.8.2 Insufficient support from power companies

CLP has introduced the “Power Connect Programme” aimed at encouraging all energy users to reduce energy consumption and offering electricity charge reductions for the underprivileged.

MS patients are however not recognized as beneficiaries under the CLP Power Connect Programme. This exclusion is due to their lack of “Disability Allowance” eligibility, inability to obtain the “Registration Card for People with Disabilities,” or be part of the “Comprehensive Social Security Assistance (CSSA) Scheme with Transport Supplement.” Consequently, MS patients face increased electricity expenses when their symptoms worsen, as they rely on heat dissipation devices such as fans and air conditioning to alleviate discomfort in rising ambient temperatures.

In addressing the financial stress experienced by MS patients, all interviewed individuals perceive subsidies on electricity expenses as the most effective solution to alleviate their financial burden. For example, MS Patient D, a former director of the Hong Kong Neuro-Muscular Disease Association, believes that subsidizing electricity costs for MS patients is a practical approach to reducing their financial outlay (Interview 2). Furthermore, MS patient C acknowledges that such subsidies can alleviate stress and concerns about the financial well-being of MS patients (Interview 5). These insights underscore the importance of providing electricity expense subsidies for MS patients to enhance both their physical and mental well-being.

5.8.3 Unawareness and limited support of the civil society

While the website of the Hong Kong Neuro-muscular Disease Association provides a basic understanding of the heat sensitivity experienced by MS patients, this study cannot find discussion about Uhthoff's Phenomenon and strategies to alleviate exacerbated MS symptoms during temperature increases. The lack of information on heat-induced MS symptoms on the organization's website suggests a general lack of knowledge of these issues within the association.

Furthermore, during the interview, MS Patient D, the former director of the Hong Kong Neuro-Muscular Disease Association Limited, expressed surprise at the existence of an air-conditioning subsidy provided by the Taipei City Government for MS patients to alleviate their worsening symptoms due to rising temperatures, as detailed in Section 2.4 (Interview 2). This lack of awareness indicates that self-help non-profit organizations in Hong Kong may not fully recognize the potential impacts of temperature increases on MS symptoms. Consequently, MS patients in Hong Kong may face challenges in accessing heat dissipation devices, such as cooling vests, leading to increased electricity expenses during temperature spikes.

6. CONCLUSION

Understanding the social implications of climate risks remains a fundamental challenge in the existing literature. In particular, the impacts on vulnerable groups, and in particular patients with chronic illnesses, remain underexplored. Chronic disease patients in developed and developing cities have received little attention in the academic literature and policy developments.

We aim to advance the literature on climate governance and fill in the gaps by conceptualising climate impacts on vulnerable groups in Hong Kong through a multidimensional framework. Our framework highlights the multidimensional impacts of rising temperatures on vulnerable groups, particularly in terms of physical, mental, and social impacts. We illustrate the dynamics conceptualised in the framework using the case study of MS patients in Hong Kong. The case study demonstrated that the framework offers a versatile tool for identifying the impacts of climate change on vulnerable groups in Hong Kong. As MS patients commonly face the negative effects of rising temperatures, this framework is also applicable internationally in other cities that share similar challenges of climate warming. This study identified critical vulnerabilities in Hong Kong, confirming that climate risks have significant impacts. We consider the framework to be applicable to a wide range of public policy areas, such as healthcare, urban planning, or disaster management.

Our findings have policy implications. Identifying these vulnerabilities suggests that targeted interventions are necessary to mitigate the effects of climate risks on these populations. In addition, subsidies on electricity expenses are the most pertinent suggestion to alleviate the exacerbation of MS symptoms. In this sense, we suggest that governments should preferentially implement electricity subsidies for MS patients in Hong Kong.

There are limitations of this study. The limited number of participants in this study may not fully capture the diversity and variability within the broader MS patients in Hong Kong. For future studies, larger sample sizes are recommended to identify more generalized findings of climate impacts on vulnerable groups.

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