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RESEARCH ARTICLE

Indoor Microclimate and Health in Vulnerable Older Adults

Jean Woo[1,2], Michelle Kwan[1], Wui Ling Chu[1], Regina Lo[1], Emma Su[1], Eric TC Lai[1,2], Richard Lee[1]

[1]Jockey Club Institute of Ageing, The Chinese University of Hong Kong, Shatin, New Territories, Hong Kong SAR, China.

[2] Department of Medicine and Therapeutics, The Chinese University of Hong Kong, Shatin, New Territories, Hong Kong SAR, China.

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Corresponding Authors: Jean Woo, Department of Medicine & Therapeutics 9/F, Lui Che Woo Clinical Sciences Building Prince of Wales Hospital, Shatin, N.T. Hong Kong SAR, China.

Abstract

There are few studies of indoor microclimate in geographical areas in subtropical as well as humid environments. During the summer period from May to October in 2024, vulnerable older adults in two districts of Hong Kong received home visits by two non-government organizations with the objective of determining whether the health impact of hot weather may be mitigated by raising health literacy relating to various preventive measures, home modification, distribution of cooling resources, and identification of heat-related illnesses and symptoms. A thermo-hygrometer was given to each participant to be placed at home for the monitoring of indoor temperature and humidity, the combined effect expressed as the humidex value. Information was collected relating to physical and mental health. Blood pressure and pulse rate were also measured during the visit. Features of the living accommodation were also recorded. No correlation between indoor humidex with thermal comfort or other health indicators was observed, with the exception of a weak negative correlation with diastolic blood pressure (r=-0.112, p=0.038, n=343), and a positive correlation with pulse rate (r=0.112, p=0.038, n=343). Seventy-eight percent (271/346) of flats had lower humidex indoors compared with outdoors. Sixty-three percent of the latter were public housing compared with privately owned flats, while flats with window orientation facing East and West had higher indoor humidex compared with other orientations. These findings inform mitigation strategies for the health impact of heat on vulnerable older population, that takes into account indoor microclimate and housing physical characteristics.

Keywords: Temperature, Humidity, Older Adults, Frailty, Building Characteristics.

1. Introduction

Global warming has given rise to widespread concerns relating to the health impact of heat (1). High temperatures increase the risk of suffering from cardiovascular, respiratory diseases and other thermal diseases (2). While there are universal features of the effect of heat on the human body, there are variations worldwide depending on human adaptations in different climatic regions, urban planning, building structures, and affordability of cooling devices (3, 4). At the same time, population aging all over the world necessitates considerations that are particularly relevant to older adults, who may be particularly vulnerable due to declining physical and cognitive function, multi-morbidity, declining social network, loneliness, and higher risk of poverty and poor housing conditions. Many countries have developed heat response plans for the general populations, covering working or leisure activities in outdoor environments, heat related symptoms and various cooling strategies (5). However few

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heat response plans specifically target vulnerable older adults, who have mobility problems and spend the majority of time indoors, and have poor social support. Few studies examine the difference between outdoor and indoor temperatures, the assumption being that indoor and outdoor temperatures are closely correlated. However, a difference exists as a result of building characteristics itself, ventilation, use of cooling devices etc. Furthermore, few studies take into account the combination of humidity and temperature in an indoor environment. How indoor microclimate affects health is important in devising heat response plans (for example advising people to stay indoors when it is hot), and more importantly in preventing adverse health impacts for those who may be confined indoors as a result of frailty or disability.

Many epidemiological studies examining the health impact of heat uses mortality, hospital admissions, and thermal comfort as indicators of health impact (6). For example an index based on a combination of heat and humidity (humidex) was developed to quantify human discomfort and mapped over Canada (7). Humidity is an important factor since high humidity reduces sweat evaporation and impedes cooling of core temperature. Subsequently humidex has been used as an indoor thermal comfort predictor in countries with high humidity (8). To date there is uncertainty regarding indoor temperature thresholds at which adverse health outcomes occur. A global systematic review carried out in 22 countries, mainly in Europe with no countries with high humidity, showed that high indoor temperatures have direct and indirect effects on health. These include increase in respiratory symptoms, core temperature, heat related health complaints, and fall in blood pressure, and physical functioning. Adverse effects on mental health also occurred, in aggravation of symptoms of schizophrenia and dementia (9). Air conditioner use largely reflects global inequality (4). There are few studies on vulnerable older adults. A survey in Adelaide South Australia revealed various needs and risk factors relating to socioeconomic and environmental conditions, behavioural, presence of chronic disease and general health status. Air conditioner use was suboptimal, and use was limited by cost concerns (10, 11). A study in Netherlands during a heat wave showed that indoor temperature and frequency of heat-related symptoms were higher than that for outdoors (12), which may be a reflection of building characteristics that retain heat rather than promote cooling.

There are few studies of indoor microclimate in geographical areas in subtropical as well as humid environments. This study examines the impact of indoor microclimate as measured by humidex on health of vulnerable older people in Hong Kong, where there is also a trend of rising temperatures, as well as high humidity, high building density leading to the existence of heat islands, and small living space per person. Although air conditioners are pervasive, use is limited by cost concerns among the poor (13).

2. Methods

An action research project was carried out during the six months of the summer period from 1st May to 31st October in 2024, including the recruitment phase, with the objective of determining whether the health impact of hot weather among older vulnerable adults living in the community may be mitigated by raising health literacy relating to various preventive measures, home modification, distribution of cooling resources, and identification of heat-related illnesses and symptoms, through home visits by two non-government organizations with the support of a Charitable Foundation. Vulnerability criteria (determined by the administration of a questionnaire) include seven characteristics: frailty (as defined by the 5 item frailty scale) (14), those who are taking five or more medications for chronic diseases, living in public housing or other housing with poor conditions, living alone or in elderly-only households, having financial difficulties, those who are home bound, and those aged 85 years or older. A score of 1 was assigned to each characteristic, with a maximum score of 7. A thermo-hygrometer was given to each participant to be placed at home for the monitoring of indoor temperature and humidity. At the home visit, the indoor temperature and humidity were recorded, without use of fans or air conditioners, together with the outdoor values given by the Hong Kong Observatory. Information was collected relating to physical and mental health : self-rated health (5-item scale), number of times consulting doctors in the previous two months, irritable mood or insomnia during hot weather (yes/no), feeling comfortable indoors when only using a fan (5-item scale), feeling anxious or depressed (5-item scale), instrumental activities of daily living (6-item scale), use of medications for hypertension, dementia, anxiety or depression (yes/no). This information was sought based on previous observations that these symptoms may occur with high indoor temperature (9). Blood pressure and pulse rate were also measured during the visit. Features of the living accommodation were also

recorded: orientation of the windows, floor (whether top floor/roof, or lower floors), whether windows can be opened, availability of air conditioner, fans, whether the ceiling is concrete or metal, whether the living space is full of clutter or not. The study was approved by the Survey and Behavioural Research Ethics Committee of the Chinese University of Hong Kong (reference No.SBRE-23-0582). All participants signed a written informed consent form.

Since cooling of core temperature is influenced by humidity, a measure combining both temperature and humidity could suitably be used to examine impact on thermal comfort (often used as an indicator of health impact of heat) and other health indicators. Humidex represents such a measure and is calculated using the method by Masterton & Richardson (7).

Associations between humidex and various health indicators were assessed using Pearson's coefficient for continuous variables and Spearman's rank correlation for categorical variables. Logistic regression was used to adjusting for medication use (medications for hypertension, dementia, anxiety, or depression). Participants' homes were also divided into two groups: indoor humidex lower than outdoors (cooler indoors) and indoor humidex higher than outdoors (hotter indoors), and health indicators and physical characteristics of the accommodation were compared between the two groups, using analysis of variance.

3. Results

Participant profiles are shown in Table 1. 21% were aged 85 years and over; 83% were pre-frail or frail; 40% were taking five or more medications, 50% lived alone, over 50% had financial difficulty, and 11% were home bound. During the period of observation, values for outdoor temperature and humidex were generally higher than those for indoors. The median (min, max) value for outdoor temperature is 30.8 (24.8-35.2), for indoor temperature is 29.6 (24.4-33.0), for outdoor humidex is 43.8 (31.2-56.5), and indoor humidex 40.6 (26.7-49.8). No correlation between indoor humidex with thermal comfort or other health indicators was observed, with the exception of a weak negative correlation with diastolic blood pressure ($r=-0.112$, $p=0.038$, $n=343$), and a positive correlation with pulse rate ($r=0.112$, $p=0.038$, $n=343$). Seventy-eight percent (271/346) of flats had lower humidex indoors compared with outdoors. Sixty-three percent of the latter were public housing compared with privately owned flats (ANOVA $p<0.001$), while flats with window orientation facing East and West had higher indoor humidex compared with other orientations (ANOVA $p=0.029$). No other building features or health indicators were found to be significantly different between the two groups.

Table 1. *Participant profile*

		N (%)
Age	<85 years old	275 (79.5%)
	85+ years old	71 (20.5%)
Frailty Level	Robust = 0 score	58 (16.8%)
	Pre-frail = 1-2 scores	168 (48.6%)
	Frail = 3-5 scores	120 (34.7%)
Medication	Less than 5 medications	208 (60.1%)
	5 medications or above	138 (39.9%)
Housing	Public Housing	195 (56.4%)
	Home Ownership Scheme Flat	16 (4.6%)
	Private Housing (Owned/ Rented)	113 (32.7%)
	Subdivided Unit/ Rooftop House	22 (6.4%)
Living Arrangement	Solitary	172 (49.7%)
	Couple	123 (35.5%)
	Others (ie. living with family)	51 (14.7%)
Financial Difficulty	Very insufficient	30 (8.7%)
	Insufficient	160 (46.2%)
	Just right	128 (37.0%)
	Sufficient	26 (7.5%)
	Very sufficient	2 (0.6%)
Home Bound	Yes	39 (11.3%)
	No	307 (88.7%)

Total Risk Score	0	1 (0.3%)
	1	21 (6.1%)
	2	54 (15.6%)
	3	90 (26.0%)
	4	89 (25.7%)
	5	68 (19.7%)
	6	18 (5.2%)
	7	5 (1.4%)

4. Discussion

The findings show that few heat-related symptoms or thermal discomfort were observed in the home environment during the summer months with outdoor temperatures ranging from 25 to 35 degrees celsius, in contrast to previous findings that are mainly outdoor observations, and also indoors in temperate zones where symptoms occur at much lower temperatures (7, 9). The findings were also unexpected since a composite measure of temperature and humidity was used as an indicator of microclimate, and one may expect that high humidity may result in more discomfort and symptoms compared with a low humidity reading although the temperature itself may be the same. It is possible that this group of vulnerable older adults represent those with impaired homeostatic mechanisms in response to environmental stressors, or that they tend to be inactive at home and have lower metabolic rates and perhaps lower core temperatures. The lack of response may also be a result of adaptation to hot weather in coping with the increasing trend of global warming. The findings are supportive of the general advice for people to stay indoors when very hot weather warnings are issued by the Hong Kong Observatory, since over 78% of housing had a lower humidex indoors compared with outdoors. It is also reassuring since older adults may be homebound and are dependent on others to go out. However, heat related symptoms and thermal comfort may not be good indicators of health impact of heat among this population, contrary to the proposal of using humidex as an indicator of thermal comfort (8). This may be due to geographic differences in climatic conditions, as well as differences in characteristics of buildings where people live.

The findings also provide insight regarding the relationship between building characteristics and indoor microclimate. The majority of housing in Hong Kong are flats in high rise buildings, exposed to wind from the land mass in the mainland China, as well as wind from the Pacific Ocean. Housing is broadly divided into public housing built by the government (Housing Authority) and rented out at low rent, or privately built. The latter may include very old low- rise houses, which may be subdivided into flats, cubicles, or bed spaces for private rental. These housing may not have windows, natural lighting, or good ventilation, while the former has building standards stipulating minimum height and floor area, natural lighting and ventilation. However, there is a long waiting list for these flats and many older adults who are poor can only afford to rent substandard private accommodation. Most homes with lower humidex readings fall into the public housing type, while homes that have higher humidex readings belong to the private sector. An East West orientation was also found to result in higher indoor humidex readings. Consideration of these factors may guide home modifications that may promote a cooler indoor environment in Hong Kong housing, in the context of global warming.

As part of public health advice during very hot weather, strategies to optimise indoor microclimate may include use of low cost thermos-hygrometers to monitor indoor conditions, use of dehumidifiers, installation of ventilation fans where appropriate, use of reflective window shades, and fans. It is uncertain whether ceiling fans or upright fans may be more efficient in cooling. However, the public should be informed that fans are not effective in reducing core temperature in older adults exposed to hot indoor temperatures of greater than 33-35 degrees celsius (15). Air conditioners will need to be used, and additional measures such as government subsidies for electricity, provision of community cooling centres, or organizations of various social activities in air-conditioned environments would reduce the duration of exposure to extreme heat. Regular home visits to vulnerable older adults would also be part of the strategy to mitigate health impact of hot weather.

There are limitations in this study, since it is more of a fact-finding study to assess health impact of heat in vulnerable older adults focusing on their home environment. The sample may not be representative of all vulnerable older people as there may be a selection bias in the recruitment process, where home

visits by strangers may be considered intrusive. The findings are applicable to the Hong Kong population only who have been acclimatised to a habitual range of temperature and humidity and may be different for different geographic regions. The strengths are that a systematic study of indoor microclimate among vulnerable older adults who may be spending more time indoors has not been done in this region, and the information obtained will inform heat action plans for older people in the general context of climate change.

Author Contributions

Conceptualization: Jean Woo

Data curation: Michelle Kwan, Wui Ling Chu, Regina Lo, Emma Su

Formal analysis: Jean Woo, Michelle Kwan, Wui Ling Chu

Funding Acquisition: Jean Woo, Eric TC Lai, Richard Lee

Investigation: Michelle Kwan, Wui Ling Chu, Regina Lo, Emma Su

Methodology: Jean Woo, Wui Ling Chu, Richard Lee

Supervision: Jean Woo, Eric TC Lai, Richard Lee

Validation: Jean Woo, Michelle Kwan

Writing – original draft: Jean Woo, Michelle Kwan

Writing – review & editing: Jean Woo, Michelle Kwan, Eric TC Lai, Richard Lee

Declaration of Interest

The authors report no conflict of interest.

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