



Effects of high temperature on existing allergic symptoms and the effect modification of allergic history on health outcomes during hot days among adults: An exploratory cross-sectional telephone survey study

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ARTICLE INFO

Keywords:

Allergy
Symptoms
Hot days
High temperature
Adults

ABSTRACT

Objective: The effects of high temperature on existing allergic conditions are unclear. This study explored the prevalence of allergic symptoms and the effects of high temperature on existing allergic symptoms among an adult population. The effects of high temperature on other non-allergic health outcomes were compared between adults with and without a history of allergic symptoms.

Method: A cross-sectional telephone survey study was conducted in Hong Kong two weeks after a heat wave in 2017. Socio-demographic information, history of allergic symptoms, non-allergic health symptoms and self-reported changes of allergic symptoms during the study hot period were collected using multiple-choice questions.

Results: Of the 436 respondents, 24% had reported an allergic history. During the study hot period, 22.4% and 15.7% of those who had skin and nasal allergies had reported worsen symptoms comparing to normal days. Comparing to people without an allergic history, those ever having allergic symptoms reported a higher rate of mucus secretions, mouth ulcers, poorer sleeping quality and worsen mood during the study hot period. The main limitation of this study is the lack of baseline information and the changes in symptoms were based on self-report basis.

Conclusion: A noticeable proportion of the study adult population reported an allergic history. Some of these symptoms got worse during period of high temperature. Pre-existing allergic symptoms were found associated with more adverse health effects and worse quality of life during hot days. Strategic health promotion policy should be planned to increase the awareness of the potential impacts of high temperature on allergy and the related health issues.

1. Introduction

Allergy, including asthma, rhinitis, eczema, conjunctivitis, urticaria, food allergy and anaphylaxis, is a hypersensitivity reaction initiated by immune system (World Health Organization, 2003). According to the World Allergy Organization (WAO), estimated allergy prevalence by country ranged between 10 and 40% (Pawanker et al., 2013). The prevalence is increasing particularly in developing regions and among children (Pawanker et al., 2014; Gupta et al., 2007; Kim et al., 2016; Banac et al., 2013) which was possibly associated with ‘Westernized’ lifestyles and urbanizations (Pawanker et al., 2013). Risk factors of allergic diseases include genes, allergens, pollution, socio-economic factors, climate, and migration (Pawanker et al., 2013). Climate and climate change affect allergic diseases and asthma in both direct and

indirect ways (Pawanker et al., 2013). For instance, high temperature was found associating with respiratory problems (Pawanker et al., 2013; Hayes et al., 2012; Voelker, 2012) and hives (Deacock, 2008; Ducommun et al., 2008) as well as distribution of pollutants and pollens (Pawanker et al., 2013; Low et al., 2011). With the face of climate change, average global temperature and frequency of extreme temperatures are increasing. This may alter the level of human exposure to high temperature as well as the pattern of allergens and pollutant which may further serious disease burden.

Majority of previous allergy studies were on asthma and wheezing (Genuneit et al., 2017). The commonest studied risks factors of allergy were microbes, genetics, pollution and allergens (Genuneit et al., 2017). Prevalence of other allergic conditions such as rhinitis, eczema and urticaria, and the association between ambient temperature and

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allergy were less studied comparatively (Low et al., 2011; Hyrkäs et al., 2014; Manuyakorn et al., 2015; Khosravi et al., 2014; Notas et al., 2015). The evidence for adults are even rarer. In Hong Kong, most of the previous allergic studies were on children which relevant prevalence figures were not available for adults (Wong and Leung, 2015). It was recommended by the WAO that learning the true burden of the diseases, initiating environmental control measures, and rising the public awareness of diseases and prevention were essential to decrease the disease burden (Pawanker et al., 2013). Knowing the prevalence and distribution of allergic disease is important in burden estimation. Understanding the association between allergic conditions and high ambient temperature, an exposure which is non-avoidable and is likely growing, would be crucial in health protection through implementing health promotions, setting up temperature-friendly environment, and building alert system.

This exploratory study was to explore the prevalence of allergic symptoms and the short-term association between high ambient temperature and pre-existing allergic symptoms among adults population. Vulnerability to high temperature was also compared between people with and without history of allergic symptoms. Self-reported health symptoms of adult respondents during a 2017 heatwave in Hong Kong were collected using a cross-sectional telephone survey as a proxy to estimate the short-term effect of high temperature on allergic symptoms. This study also compared the sensitivity to high temperature between people with and without allergic conditions.

2. Methods

2.1. Study design and data

In the period from 25th July to 30th July 2017, Hong Kong had experienced a heat wave with average daily mean temperature over 30.2 °C for consecutive 7 days (average daily temperature = 28.7 °C, in the same period during 1981–2010) (Hong Kong Observatory, 2017a). In particular, relative low wind speed (< 10km/hour) (Hong Kong Observatory, 2017b) and very high level of air-pollutants (reached the highest air-quality index 10/10+) (Environmental Protection Department, 2017) were recorded on 29th and 30th July. To capture the possible adverse health outcomes associated with the extreme environmental conditions in this particular week, a cross sectional telephone survey study was conducted two weeks after the heat wave started (7th August – 13th August 2017). The survey collected socio-demographic information, history of chronic diseases and allergic symptoms, adverse non-allergic health symptoms and changes of allergic symptoms during the heat wave and sensitivity to ambient conditions from respondents using multiple-choice questions (Table 1). The survey was conducted by a professional telephone survey laboratory to ensure consistency and quality.

The respondents of this heat wave survey were recruited from the samples in our two previous cold wave and health studies in 2016 and 2017(21). The samples in the 2016 and 2017 cold wave survey were recruited by adopting a computer randomized dialing telephone survey with the land-based telephone list in the Hong Kong population and the respondent for each household was selected using the last birthday approach. The cold wave samples were population-matched to the Hong Kong Census 2011 in terms of distributions of age-group, gender and residential district with sample size of 1017 and 1000, respectively. All respondents were 15 years old or above, Cantonese speaking and were Hong Kong residents. The detailed information of sampling for the cold wave surveys have been published elsewhere (Chan et al., 2017). Only subjects that had agreed to be contacted again in the cold wave studies were invited for this heat wave study. Oral consent was sought at the beginning of each telephone survey. Ethics approval for this study was granted by the Survey and Behavioral Research Ethics Committee, the Chinese University of Hong Kong.

2.2. Statistical analysis

Socio-demographic characteristics, history of chronic diseases and allergic symptoms and changes of allergic symptoms of respondents were summarized using descriptive statistics. Simple logistic regression was adopted to identified the associating factors of worsen allergic symptoms during the heatwave. Chi-square test (with continuity test for binary variables and trend test) was used to identify the predicting factors of the presence of allergic symptoms and to explore non-allergic health symptoms that associated with the history of allergic symptoms. Associations with p-value less than 0.05 were considered statistical significant. All statistical analyses were done by using IBM SPSS statistics 21.0.

3. Results

A total of 436 subjects were recruited for this allergic symptom survey. The overall respond rate was 42.9%. About 70% respondents were respondents in 2017 cold wave survey and 30% were from the 2016 cold wave sample. The personal characteristics and descriptive results are presented in Table 1.

3.1. Prevalence of allergic symptoms and the socio-demographic characteristics of the people with allergic symptoms

About 24% (104/436) of respondents reported a history of allergic symptom (Table 1). Prevalence of allergic symptoms for females was 26.8% and that for males was 20.4% (Table 1). Among all respondents, 13.3% reported ever having skin allergy, 11.7% reported nasal allergy, and 2.5% reported other respiratory allergy (Table 1). Only 0.2% and 0.5% reported ocular allergy and gastrointestinal allergy (Table 1). There were no evidences showing that allergic symptoms were associated with household income, education level and history of chronic disease (Table 1). However, attention should be paid that the distributions of socio-demographic characteristics of the study sample were not comparable to those reported in the Hong Kong Census since this study sample was recruited through a follow up sample of a previous cold wave study. Further studies with larger sample size or with population characteristics match with the population will be need to verify the prevalence of allergic symptoms and its pattern.

3.2. Change of allergic symptoms during study heat wave and the associating factors of worsen allergic symptoms

Among those who ever have skin allergic symptoms, 22.4% (13/58) felt the allergic symptoms got worse and 12.1% felt better during the study heat wave (Table 2). Fifteen point seven percentage (8/51) of those ever have nasal allergic symptoms felt the symptoms got worse while 7.8% (4/51) felt better during the study heat wave (Table 2). The percentage of feeling better and feeling worse for the symptoms were the same (18.2%, 2/11) for those who ever have respiratory allergic symptoms (Table 2). The worsen allergic symptoms during the study heat wave did not appear to be associated with age, gender and household income but was shown to be associated with residential districts and other non-allergic symptoms reported during the study heat wave (Table 3). People who resided in Hong Kong Island (vs. Kowloon) and who reported gastrointestinal pain during the study heat wave were more likely to have worsen skin allergic symptoms (Table 3). People who reported musculoskeletal pain during the study heat wave were more likely to have worsen nasal allergic symptoms (Table 3). Subgroup analyses in other allergic symptoms were not conducted because of the small sample size. Due to the limited sample size, only simple logistic regressions were performed and therefore the presented association were not adjusted by socio-demographic factors.

Table 1

Percentage of self-reported allergic symptoms, socio-demographic characteristics and self-reported medical history of subjects.

Ever have allergic symptoms (self-reported)		n (%)		Total (N)	p-value#
		Yes	No		
Type of allergic symptoms reported	Skin	104(23.9)	332(76.1)	436	
	Nasal	58(13.3)			
	Other respiratory	51(11.7)			
	Ocular (Eye)	11(2.5)			
	Gastrointestinal	1(0.2)			
	Others	2(0.5)			
	Don't know	3(0.7)			
Gender	Male	1(0.2)			
	Female	41(39.4)	160(48.2)	201(46.1)	0.117
Age	15–24	63(60.6)	172(51.8)	235(53.9)	
	25–39	16(15.4)	48(14.5)	64(14.7)	0.108
	40–59	17(16.3)	52(15.7)	69(15.8)	
	60–69	42(40.4)	105(31.6)	147(33.7)	
	≥ 70	21(20.2)	66(19.9)	87(20.0)	
Monthly Household Income (HKD)	< 10,000	8(7.7)	61(18.4)	69(15.8)	
	10,000–19,999	15(15.8)	62(19.8)	77(18.9)	0.926
	20,000–29,999	17(17.9)	53(16.9)	70(17.2)	
	30,000–39,999	16(16.8)	54(17.3)	70(17.2)	
	≥ 40,000	15(15.8)	44(14.1)	59(14.5)	
Education Level	Primary school or below	32(33.7)	100(31.9)	132(32.4)	
	Secondary school			408	0.508
	Post- Secondary level	11(10.7)	48(14.5)	59(13.6)	
	Bachelor or above	49(47.6)	155(46.7)	204(46.9)	
Residential District	Hong Kong Island	11(10.7)	45(13.6)	56(12.9)	
	Kowloon	32(31.1)	84(25.3)	116(26.7)	
	New Territories			435	0.760
History of Chronic Diseases (Self-report)*	Yes	20(19.2)	50(15.1)	70(16.1)	
	No	36(34.6)	104(31.3)	140(32.1)	
		48(46.2)	178(53.6)	226(51.8)	
				436	0.850
		33(31.7)	108(32.7)	141(32.5)	
		71(68.3)	222(67.3)	293(67.5)	
				434	

Remarks: Number of subjects not sum to 436 due to missing.

#p-value for Chi-square test between with and without history of allergic symptoms.

*Respondents were asked if they had any history of chronic diseases. The definition of chronic diseases in the survey was any diseases that required medical treatment longer than 6 months.

Table 2Changes of major allergic symptoms during study period^a.

History of allergy	Change of allergic symptoms during the heatwave	n	% among Total
Skin allergy	Worse	13	22.4
	Unchanged	38	65.5
	Better	7	12.1
	Total	58	100.0
Nasal allergy	Worse	8	15.7
	Unchanged	39	76.5
	Better	4	7.8
	Total	51	100.0
Respiratory allergy	Worse	2	18.2
	Unchanged	7	63.6
	Better	2	18.2
	Total	11	100.0

^a Study period: 7–13/8/2017.

3.3. Comparing other health outcomes during hot days, sensitivity to ambient temperature and medical consultation behavior between people with and without allergic symptoms

During the heat wave, those who reported an allergic history were more likely to report poorer sleeping quality and worsen mood than those who did not have allergic symptoms (Table 4). No differences in social interactions and appetite were seen between groups. Among the study non-allergic symptoms, increased secretion of mucus and mouth ulcer were more likely to be reported by those who had an allergic

history (Table 4). People with allergic symptoms were also shown to be more sensitive to both high and low temperature. The average temperature that people ever have allergic symptoms started feeling hot (cold) were 0.8 °C (1.0 °C) lower (higher) than that for people without allergic symptoms (Table 5). However, compare to those without allergic symptoms, these group of people were less likely to consult a doctor when they had non-allergy related adverse health conditions (Table 4).

4. Discussions

This study found that about 24% adults have reported ever having at least one allergic symptoms. Among those who had reported specific allergic symptoms, 22.4% and 15.7% thought their skin and nasal allergic symptoms got worse during the study heat wave. Compared to those did not report any history of allergy, people who had an allergy history were more likely to reported other non-allergic health symptoms including increased mucus secretion and mouth ulcer during the study heat wave. Furthermore, these group of people were more likely to report worsen sleeping quality and mood during the study heat wave. Respondents with allergic conditions were shown to be more sensitive to temperatures. They started feeling cool at a warmer temperature and started feeling hot at a cooler temperature than those who had no allergy history, although the difference were small. Despite the poorer health outcome and quality of life reported by those who ever had allergic symptoms, they showed a lower proportion of medical consultation when they experienced any non-allergy health symptoms than

Table 3Associating factors and the odds ratio of having worsen allergic symptoms during the study period ^a – Simple logistic regression.

	No change/better	Worse	Odds Ratio (OR) (95% C.I.)	p-value for OR
Skin allergic symptoms (N = 58)				
Residential Districts				
Hong Kong Island	5 (50.0%)	5 (50.0%)	1.00	–
Kowloon	17 (94.4%)	1 (5.6%)	0.06 (0.01, 0.63)	0.02
New Territories	23 (76.7%)	7 (23.3%)	0.30 (0.07, 1.37)	0.12
At least one non-allergic symptoms during study heat wave				
No	27 (90.0%)	3 (10.0%)	1.00	–
Yes	18 (64.3%)	10 (35.7%)	5.00 (1.21, 20.71)	0.03
Had gastrointestinal pain during study heat wave				
No	41 (83.7%)	8 (16.3%)	1.00	–
Yes	4 (44.4%)	5 (55.6%)	6.41 (1.40, 29.22)	0.02
Nasal allergic symptoms (N = 51)				
Had musculoskeletal pain during study heat wave				
No	40 (88.9%)	5 (11.1%)	1.00	–
Yes	3 (50.0%)	3 (50.0%)	8.00 (1.26, 50.92)	0.03
^a Study period	7–13/8/2017			

^a Study period: 7–13/8/2017.

those had no allergy history. This suggested a potential higher health risk but inadequate awareness in health protection during high temperature among the allergic population.

The prevalence of allergic symptoms found in this study is within the estimated range of 10–40% reported by the WAO (Pawanker et al., 2013). Previous studies have provided evidences on the positive association between environmental exposure level, including extreme temperatures (Hyrkäs et al., 2014; Notas et al., 2015), and risk of allergic diseases (Genuneit et al., 2017; Hyrkäs et al., 2014; Notas et al., 2015; Reinmuth-Selzle et al., 2017; Shea et al., 2008). Most of the evidences were focused on asthma, allergic rhinitis and eczema (Genuneit et al., 2017) and health outcomes were mostly based on clinical records. Instead of looking at the occurrence of allergic conditions during extreme environmental conditions, this study examined the changes of allergic conditions during the change of ambient temperature. The self-reported approach is clinically less reliable but it allows the inclusion of the less severe cases that did not result in

medical consultations.

The findings showed a higher rate of overall self-reported non-allergic symptoms, worsen mood and sleeping quality during the study hot days among those ever have any allergic symptoms. This suggested that people having allergic conditions may be more vulnerable for other health symptoms during high temperature. Our results showed that the allergic group was more likely to report increased mucus secretion and mouth ulcer. Previous studies have reported comorbidity for allergic diseases such as allergic rhinitis and asthma (Ko et al., 2009; Yuksel et al., 2008; Kim et al., 2013). People have one kind of allergy may be more likely to have another kind of allergy. Mucus secretion may be one of the symptoms of allergic reaction along the respiratory tract while mouth ulcer can also be caused by allergy, although this was not commonly reported (Jinbu and Demitsu, 2014). Further study is warranted to verify the effect modification on the temperature-health association by allergic history and to investigate the biological mechanism.

Table 4Other self-reported adverse health symptoms, changes in quality of life, consulting a medical doctor in response to symptoms during the study period^a by history of allergic symptoms (Yes/No).

Number (n) and % of respondents with the health outcomes	History of allergic symptoms				Total		p-value for Chi-Square test with Continuity Correction/Pearson Chi-Square test ^a
	No		Yes		n	%	
	n	%	n	%			
Had at least one non-allergic symptoms during study period	126	38	53	51	179	41.1	0.03
Reported short of breath	14	4.2	9	8.7%	23	5.3	0.13
Reported wheezing	7	2.1	6	5.8	13	3	0.11
Reported increased secretion of mucus	30	9	24	23.1	54	12.4	< 0.0005
Reported mouth ulcer	5	1.5	6	5.8	11	2.5	0.04
Sought doctor consultation	49	38.9	18	17.5	67	29.3	< 0.005
Reported decreased social interaction during study period	81	24.4	27	26	108	24.8	0.79 ^a
Better	29	8.7	7	6.7	36	8.3	
No change	222	66.9	70	67.3	292	67	
Reported worsen appetite during study period	67	20.2	27	26.0	94	21.6	0.45 ^a
Better	19	5.7	5	4.8	24	5.5	
No change	246	74.1	72	69.2	318	72.9	
Reported worsen mood during study period	70	21.1	32	30.8	102	23.4	0.02^a
Better	42	12.7	5	4.8	47	10.8	
No change	220	66.3	67	64.4	287	65.8	
Reported worsen sleeping quality during study period	80	24.1	33	31.7	113	25.9	0.04^a
Better	42	12.7	5	4.8	47	10.8	
No change	210	63.3	66	63.5	276	63.3	

Bold: $p \leq 0.05$.^a Study period: 7–13/8/2017.

Table 5
Sensitivity to ambient temperatures by history of allergic symptoms (Yes/No).

	History of allergic symptoms						p-value for t-test
	No		Yes		Difference (No – Yes)		
	N = 330		N = 104		N = 434		
	Mean	SD	Mean	SD	Mean (Standard deviation)	95% confidence Interval	
Threshold temperature that make respondent feel hot (°C)	29.51	2.81	28.70	2.79	0.81 (0.31)	0.1862, 1.4281	0.01
	N = 324		N = 104		N = 428		
Threshold temperature that make respondent feel cold (°C)	13.18	4.53	14.19	4.58	1.02 (0.51)	− 2.03, < -0.005	0.05

Although higher health risk was found among those ever have allergic symptoms during the study period, they even showed a lower rate of medical consultation when they had any symptoms. Environmental health risk is associated with hazards, exposure and vulnerability (United Nations, 2004). Minimizing exposure is one of the solution of risk reduction. Inadequate awareness may lead to less practice of protective behavior which may further increase the risk among vulnerable groups. Strategic health promotion should be planned to raise the awareness of temperature-related health impacts and to provide guidelines for effective health protection.

Ambient temperature may associate with allergic symptoms in many ways. It alters vegetation patterns spatially and temporally (Reinmuth-Selzle et al., 2017; Shea et al., 2008). This may change the pattern of allergen factors such as longer pollen season and geographical shift of pollen distribution. Concentration of air pollutants and greenhouse gases that were found associated with higher risk of allergies especially asthma may also change according to changing weather and climatic conditions (Reinmuth-Selzle et al., 2017; Shea et al., 2008). Apart from the effects on allergens and adjuvants, temperature also increase risk of hypersensitivity through affecting the immune system. High temperature may increase the level of neutrophils count (LaVoy et al., 2011; Sampson, 2000) which neutrophils release mediators that cause bronchial epithelial damage and airway obstruction (Sampson, 2000). However, the effect of high temperature on corticosteroid levels were less conclusive in humans. (Mahima et al., 2013).

The findings of this study will be useful in evaluating the impact of heat on various allergic conditions as well as in projecting the health impacts of increasing average temperature on the allergic population due to climate change. With the increasing prevalence of allergy and the rising average global temperature, the results of this study will be served as a basis for further studies in revealing the effect of rising temperature and allergy and for drafting relevant health protection strategies.

Several limitations of this study should be highlighted. It did not measure the direct attributable risk by high temperature but compared the changes of existing allergic symptoms between the study hot period (a proxy of high temperature exposure) and any other days (the proxy of a normal day, non-hot day). The associations found might be confounded by other environmental factors such as level of air-pollutants and pollens. It should be highlighted that the level of air-pollutants during the study period were also at high level which might be associated with the changes in allergic symptoms and other health effects. The difference of proportion of reporting worsening symptoms between residential districts may reflect the effects of the location-specific environmental factors. Future study with the adjustment of other environmental confounding factors should be done to confirm the association between high temperatures and worsen allergic conditions. Baseline prevalence of non-allergic health symptoms were not available. Other personal factors like diet records and records of contact with other allergens were not available. All these might over-estimated the association between these symptoms and high temperatures. This

study used a follow up sample from another study which the characteristics of subjects was not perfectly comparable to the census data and therefore the representativeness is uncertain. The small sample size also limited the accuracy in prevalence estimation and did not allow multivariable analysis and subgroup analyses. Results from regression models reported were not adjusted for demographic and confounders and therefore should be interpreted with caution. The self-report approach with no clinical diagnosis support is another major limitation. This raised uncertainties in the accuracy in defining allergic conditions. However, as discussed, this approach allow the inclusion of less severe cases that did not need medical consultations. Respondents were asked to describe the changes of the conditions in categorical form (worse, no change and better) but the changes were not quantified.

In conclusion, the results of this study showed that about 24% of the study adults were living with allergic symptoms and suggested that some of these conditions may get worsen during the period of high temperatures. People with an allergy history were also found to be more sensitive to temperatures and have more health issues during the period, including more health symptoms and poorer quality of life. This group of people however were less willing to consult a medical doctor when they felt unwell than people without any allergy histories. With the increasing global average temperature, burden of allergic symptoms and other heat related associated health issues among people with allergic symptoms may rise. Further study in larger scale with potential confounder considered should be conducted to quantify the associations. Health care service providers, caregivers, people with allergic symptoms should be advised to increase the awareness of the potential impacts of high temperature on allergic conditions and the related health issues.

Funding

This research project was co-funded by the Chinese University of Hong Kong (CUHK) Focused Innovations Scheme – Scheme A: Biomedical Sciences (Phase 2) and the CUHK Climate Change and Health research project fund. The funders did not involve in the study.

Ethics approval

This study is approved by the Survey and Behavioral Research Ethic committee, The Chinese University of Hong Kong.

CRediT authorship contribution statement

Holly Ching Yu Lam: Conceptualization, Formal analysis, Investigation, Methodology, Validation, Writing - original draft, Writing - review & editing. **Emily Ying Yang Chan:** Data curation, Resources, Investigation, Supervision, Writing - original draft, Writing - review & editing.

Acknowledgements

The authors would like to acknowledge the research team of Collaborating Centre for Oxford University and CUHK for Disaster and Medical Humanitarian Response (CCOUC), the Chinese University of Hong Kong for their contributions in facilitating the telephone survey. Special thanks should be given to Dr. Shakoor Hajat for his valuable comments and support in this work.

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