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Pneumonia Hospitalization Risk in the Elderly Attributable to Cold and Hot Temperatures in Hong Kong

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Abstract

Potential pathogens relevant to respiratory tract infection may be triggered by changes in ambient temperature. Few studies have examined the risk of temperature on pneumonia incidence, and no studies have focused on susceptible elderly population. We aimed to examine the short-term association between ambient temperature and geriatric pneumonia, and assess the disease burden attributable to cold and hot temperatures. Daily time series data of emergency hospital admissions for geriatric pneumonia, mean temperature, relative humidity, and air pollution concentrations between January 2005 and December 2012 in Hong Kong were collected. Distributed lag non-linear model integrated in quasi-Poisson regression was used to examine the exposure-lag-response relationship between temperature and pneumonia. Attributable risk measures due to non-optimal temperature were calculated to summarize the disease burden. Subgroup analyses were conducted to examine the gender difference. We observed significant non-linear and delayed associations with both cold and hot temperatures on pneumonia in the elderly, with cold temperatures having stronger effect estimates. Among the 10.7% of temperature-related pneumonia hospitalizations, 8.7% and 2.0% was attributed to cold and hot temperatures, respectively. The majority of temperature-related burden for pneumonia hospitalizations was attributed to cold temperatures in Hong Kong, and elderly male presented greater susceptibility.

Key Words:

Attributable Risk; Distributed Lag Non-linear Model; Emergency Hospital Admission; Geriatric Pneumonia; Relative Risk; Time Series

Abbreviations:

AR, attributable risk; AF, attributable fraction; AN, attributable number; DLNM, distributed lag non-linear model; RR: relative risk; CI, confidence intervals; PM_{10}, particulate matter with aerodynamic diameter less than 10 microns.

Introduction

Pneumonia, the lower respiratory tract infections in general, is the second leading cause of death worldwide. Pneumonia affects approximately 450 million people globally per year (7% of the population) and results in about 4 million deaths (1). Whilst most deaths are recorded in developing countries, it was the second leading cause of death in Hong Kong between 2012 and 2014. Increasing trends in the number of pneumonia-related deaths and death rates have been observed since 2001. The number of deaths due to pneumonia in 2014 were 7,502, accounting for 16.4% of total registered deaths in Hong Kong (2). Male had the higher death rates than female, which were 110.8 and 81.4 per 100,000 population in 2013, respectively, and the age-specific death rates increased markedly after the age of 65. The number of in-patient discharges due to pneumonia has also continued to rise gradually in recent years (3). Low social-economic status, inadequate nutrition, exposure to tobacco smoke, air pollution and extreme weather, and not receiving immunization may be predisposing factors for lower respiratory tract infection in older people (4).

Thus far, only limited studies have examined the association between weather factors and pneumonia incidence (5–11), with most focused on pneumonia in children (5–9). Research found positive association of pneumonia-related hospitalizations or emergency room visits with increases in (1) weekly mean temperature (9), (2) daily mean temperature (6,10), and (3) the temperature change between two neighboring days (5). The weekly number of *M pneumoniae* pneumonia cases in Japan increased by 16.9% (95% CI: 11.3% - 22.8%) for every 1°C increase of the average temperature (9); and the rates of *M pneumonia* infection in hospitalized children in Suzhou, China showed a strong correlation (r=0.825) with monthly mean temperature (7). However, few studies have accounted the possible non-linear and delayed association between temperature and pneumonia (6,10), and none have targeted the elderly population.

The older population are usually more susceptible to cold and hot temperature related health risks (10,12,13). Possible causal pathways may include reduced thermoregulatory capacity and increased vulnerability to infection. In this study, we aimed to conduct a time series analysis to examine the association between ambient temperature and emergency hospital admissions for geriatric pneumonia, and to assess the disease burden attributed to cold and hot temperature under its complex exposure-lag-response relationships. Identifying the risk of ambient temperature on geriatric pneumonia will help to guide public health policy to plan interventions and prevention measures for temperature-related pneumonia for vulnerable elderly population.

Materials and Methods

Data collection

Emergency Hospital Admission data

The daily count of emergency hospital admissions for pneumonia (ICD-9: 480-486) as the principal diagnosis was obtained from the Hospital Authority Corporate Data Warehouse. The Hospital Authority is the statutory body running all public hospitals in Hong Kong. Records of admission were taken from the publicly-funded hospitals which provides 24-hour accident and emergency care, and covering 90% of hospital beds in Hong Kong for local residents (14). For the study period of 2005-2012, the Hospital Authority provided us with daily counts of emergency hospital admissions aggregated over age, gender, date of admission, and principal diagnosis on discharge. We abstracted the overall daily pneumonia emergency admissions, admissions of elderly subjects (i.e. age ≥ 65 years old) and those in different genders as the health outcomes. Analyses for childhood pneumonia (age < 15yrs) and adult pneumonia (age of 15-64yrs) were also included in supplementary materials for a more complete picture. Daily admissions for influenza (ICD-9: 487) were used to identify influenza epidemics, which were then treated as a potential confounder in the data analysis (15). Ethical approval and consent from individual subjects were not required by our institute as we used only aggregated data but not any individualized data in this study.

Temperature and Air Pollution Data

The daily mean temperature and relative humidity from January 2005 to December 2012 was obtained from the Hong Kong Observatory. Extreme cold weather was defined as daily mean temperature at or lower than the 1^{st} percentile of its distribution in study period, while moderate cold was defined as daily mean temperature between the 1^{st} percentile and optimal temperature. The extreme hot and moderate hot weather was defined using the 99th percentile as the cutoff point accordingly (16,17).

Air pollution concentrations in the same period were obtained from the Hong Kong Environmental Protection Department. We calculated the daily 24-hr mean concentrations of particulate matter with aerodynamic diameter less than 10 microns (PM_{10}) and nitrogen dioxide, and daytime 8-hr (10:00-17:00) mean ozone concentrations for each monitoring site, and then averaged them across the 10 stations (18). Air pollutants would be acted as potential confounders in the data analysis.

Statistical modeling

The relative risk (RR) of temperature exposure on emergency hospital admissions for pneumonia and each subgroup was estimated in a standard time-series quasi-Poisson regression. The association with temperature was modeled using a distributed lag non-linear model (DLNM), which was included in the model as *cross-basis* function to flexibly account for the potential lagged and nonlinear association between temperature and pneumonia hospitalizations (19). This DLNM has the advantage of estimating the associations with cumulative temperature exposure over multiple days while adjusting for the collinearity of temperature on neighboring days (20).

Specifically, we modeled the exposure-response relationship with a natural cubic spline for temperature and the lag-response relationship with a natural cubic spline for lag days, using the median value of temperature as the preliminary reference. Spline knots were placed at equal spaces in the temperature range to allow enough flexibility in two ends of temperature distribution, and placed at equally spaced values in the log scale to allow more flexible lag effects at shorter delays. The knots for temperature and lag were tested at 1 to 5 and chosen by the minimum Akaike information Criterion (AIC) for quasi-Poisson models (19,21). In the current study to examine the association between ambient temperature and pneumonia hospitalizations in the elderly, 2 knots for temperature and 4 knots for lag produced the best model fit. The lag period was extended to 21 days in order to capture the long delay in cold risks and adequately assessed hot risks after excluding emergency hospitalizations advanced only by a few days (harvesting effect) (22). The short lags could not adequately be used to assess the hot risks, as the harvesting effects are ignored (21).

We included a natural cubic spline of time with 8 degrees of freedom (*df*) per year to control for seasonal and long-term trends, a natural cubic spline of relative humidity with 3 *dfs* and dummy variables for day of the week, public holidays and influenza epidemics to control for these time varying confounders (23). Air pollutants (PM_{10}, nitrogen dioxide and ozone) as cross-basis functions with a natural cubic spline of 2 knots and a maximum lag of 3 days for pollutant concentrations, and natural cubic spline for lags with 2 knots were included in the model to control for their distributed lagged confounding effects on pneumonia hospitalizations (16).

The optimal temperature (OT), corresponding to a minimum emergency hospitalization for pneumonia in the elderly, was determined from the threshold model by setting the threshold between 18 °C to 30 °C (in 0.1°C gaps) and identified the model with minimized residual deviance (21). The value of threshold was then defined as the reference temperature (centering value) to fit the exposure-lag-response relationship between temperature and pneumonia hospitalizations. The overall risk of temperature was cumulated over the lag period. As previous studies indicated that the associations with hot temperatures were generally more short-term than those from cold temperatures while including some harvesting a few days later, besides the cumulative risk over 0-21 lag days, we also estimated the associations with temperature over the following lag periods: 0–1, 2–6, and 7-21 to represent the acute, delayed and long-lasting risks respectively (24). As the temperature-mortality or morbidity relationship was 'U' or 'J' shape in general, we calculated the relative risks (RRs) for cold and hot temperatures respectively. Specifically, we calculated the RRs for pneumonia hospitalizations at extreme cold (1st percentile of temperature distribution) and moderate cold (10th percentile), and at extreme hot (99th percentile) and moderate hot (90th percentile), compared with the optimal temperature in Hong Kong. Subgroup analyses by gender were also conducted to capture the gender difference.

Computation of attributable risk

The optimal temperature was also considered as the reference to compute the attributable risk by centering the natural cubic spline that modeled the exposure-response relationship. For each day of the series for a pneumonia subgroup, the overall cumulative RR corresponding to each day's temperature was used to compute the attributable counts and fraction in the next 21 days, using a backward approach previously described by Gasparrini and Leone that summarized the current burden due to the past exposures (25).

The total attributable number (AN) of hospitalizations due to non-optimal temperatures was given by the sum of the contributions from all the days of the series, and its ratio with the total number of hospitalizations provides the total attributable fraction (AF). The components attributable to cold and hot weather were computed by summing the subsets corresponding to days with temperatures lower or higher than the optimum, respectively. They were further separated into moderate and extreme contributions by defining extreme cold/hot as the temperatures lower than the 1^{st} percentile or higher than the 99^{th} percentile, while the moderate temperatures were the range between the optimal temperature and the cut-off (25,26).

Empirical confidence intervals (eCI) were obtained by Monte Carlo simulations assuming a multivariate normal distribution of the reduced coefficients of the cumulative effect estimate (25). We derived empirical confidence intervals for backward total AN and AF, computed overall and for separated components, by simulating 5,000 samples from the assumed distribution.

All analyses were conducted in R statistical environment version 3.1.3 (R Development Core Team, 2014), with its 'dlnm' package (20) to fit distributed lag non-linear model to estimate the association with temperature. The attributable risk measures (AF and AN) was calculated by function 'attrdl' provided by Gasparrini (27).

Results

Data Description

During the study period, a total of 197,316 emergency hospital admissions for pneumonia in subjects with age ≥ 65 years old were recorded, which accounted for 73.8% of the total pneumonia cases. On average, there were 67 emergency pneumonia hospitalizations in the elderly population per day, with 32 and 35 for female and male, respectively. The median of the daily mean air temperature was 24.7 ^{o}C with range between 8.7 ^{o}C and 31.8 ^{o}C, and the relative humidity was 79%. The daily 24-hour mean concentration was 50.5 μg/m^3 for PM_{10} and 55.9 μg/m^3 for nitrogen dioxide, while the daytime 8-hour mean concentration for ozone was 47.1 μg/m^3 (Table-1). The time-series plot shows the variation of daily mean temperature and emergency hospital admissions for pneumonia in the elderly and in different gender groups (Figure-1).

Relative Risk of Cold/Hot Temperature

The exposure-lag-response surface shows the distributed lag nonlinear relationship between ambient temperature and geriatric pneumonia emergency hospitalizations (Web Figure-1). Figure-2 shows the association with cumulative temperature exposure over 0-21 lag days, using a natural cubic spline DLNM with 2 equal spaced knots for temperature and 4 knots for lag. The temperature-hospitalization relationship was reverse 'J' shape with significant higher risk at both low and high temperature. Temperature-specific risks at 1st, 10th, 90th, and 99th percentiles relative to the optimal temperature at 25.0^{o}C over 0-21 lag days on emergency hospitalizations for geriatric pneumonia revealed that the significant cold risk appeared on lag1-2 days and lasted for 2-3 weeks, whereas the hot risk occurred acutely within lag 0-1 days, followed by some harvesting on lag 2-6 days and kept relatively low risk over the longer lags (Table-2). The exposure-response relationship between relative humidity and pneumonia hospitalizations in elderly was shown in Web Figure-2. Although there was no statistical significance, a slightly positive association between pneumonia hospitalizations and the same day relative humidity was found.

As indicated in table-2, the associations with temperature varied by lag periods. The overall RRs for cold temperatures were non-significant on lag0-1 days; RRs started on lag2 day and generally lasted for three weeks. Compared with 25^{o}C the optimal temperature, the cumulative RR over 0–21 lags days for geriatric pneumonia hospitalizations was 1.61 (95%CI: 1.43-1.81) for extreme cold (1st percentile, 11.2 °C) and 1.35 (95%CI: 1.22-1.49) for moderate cold (10th percentile, 15.8 °C), both higher than the effect estimates from the general whole population. The cold risks were significantly stronger for male than female. The hot temperature showed acute effect estimates on geriatric pneumonia on lag0-1 day, and the cumulative RR over 0-21 lag days was 1.13 (95%CI: 1.03-1.23) for extreme hot (99th percentile, 30.6 °C) and 1.08 (95%CI: 1.01-1.16) for moderate hot (90th percentile, 29.4 °C), comparing with the optimal temperature (Table-2). The hot risks did not show much differences between genders. The exposure-response curves show the consistent associations between cold/hot temperature and hospitalizations for pneumonia in the elderly and by gender (Figure-3).

We have also explored the associations in different age groups, including pneumonia hospitalizations among children, adults, and elderly, respectively. As shown in the Web Figure-3, childhood pneumonia was not associated with cold temperature; adult pneumonia was not associated with either hot or cold temperatures. It should be noted, however, among the total pneumonia cases, only 12.7 and 13.5 percent of them were children and adults, respectively. The relatively smaller sample size could reduce the study power in examining the relationships among these two pneumonia groups.

Attributable Risk of Cold/Hot Temperature

The optimal temperature corresponding to the minimum emergency hospitalizations for geriatric pneumonia identified in Hong Kong was 25.0°C. It was used as the reference point for computing the attributable risk measures. Table-3 shows estimates of AF and AN for geriatric pneumonia attributed to non-optimal temperature, separated by cold and hot risks. It was found that cold weather was responsible for most of the burden, while the fraction due to heat was more limited. There were 10.7% of emergency hospitalizations for geriatric pneumonia attributed to non-optimal temperature, of which 8.7% and 2.0% was due to cold and hot weather, totaling 17,102 and 3,981 cases during the 8 years' study period, respectively. Elderly male showed significantly higher AF attributed to cold than female (12.5% vs. 3.9%), however, not much different AF was found attributed to hot weather between genders (2.2% vs. 1.8%).

We further separated the contributions from cold and hot weather into moderate and extreme temperatures. Results showed that the moderate temperature accounted for the vast majority part of the pneumonia hospitalizations attributable to temperature. Among the 8.7% of geriatric pneumonia hospitalizations attributed to cold weather, 8.1% was from moderate cold (11.2~25.0 ^{o}C), while the 1.9% was from moderate hot (25.0~30.6 ^{o}C) in the total of 2.0% attributable to hot. This phenomenon was similar for both genders.

Discussion

In this study, we examined the association between ambient temperature and emergency hospitalizations for pneumonia in elderly population in Hong Kong. We observed significant non-linear and delayed risks of both cold and hot temperatures on geriatric pneumonia. Cold temperatures showed considerably higher risk on the pneumonia incidence than hot temperature. Although the relative risks were greater for extreme temperatures, the majority of the hospital admissions were attributed to moderate cold weather. Gender differences were also observed - elderly male showed significantly greater susceptibility to the cold than female.

Although the associations between weather factors including sunshine, temperature, humidity and clinical pneumonia have been established in the literature (8,9,28), few studies have examined the short-term association between ambient temperature and pneumonia incidence (Liu et al. 2014; Xu et al. 2014b). A study conducted in Shanghai, China observed a V-shape relationship between daily mean temperature and pneumonia hospitalizations, with optimum temperature at 18^{o}C for subjects older than 65 years (10). In that, a 5% increase in daily pneumonia hospitalizations per 1^{o}C decrease in temperature of lag4 day below the optimum was recorded, however, the distributed lags effect was not considered which may underestimate the true association. Another study conducted in Brisbane, Australia used temperature estimated from satellite remote sensing and DLNM model to examine its risks on emergency department visits for childhood pneumonia (6). They reported an optimum temperature of 23^{o}C and found that both low and high temperatures were associated with increase of childhood pneumonia onset. However, associations with pneumonia in the elderly was not reported. In the current study, we observed significant positive effect estimates for both cold and hot temperatures over 0-21 lag days on geriatric pneumonia, which was the first study to explore the non-linear and delayed association between ambient temperature and pneumonia hospitalizations in the elderly.

Biological plausibility for the association and the gender difference

Several underlying mechanisms have been proposed in explaining increased pneumonia risk associated with exposure to cold and hot temperatures. It was suggested that cold weather would induce broncho-constriction and suppress mucociliary defences and other immunological reactions, resulting in local inflammation and increased risk of respiratory infections (29). Exposures to hot weather may trigger acute reactions when body exceeds its thermoregulatory threshold. Meanwhile, hot weather is always accompanied with high humidity in summertime in Hong Kong. Hot and humid conditions provide suitable environments for the spread of fungal spores, bacterium and virus, from which may be inhaled and subsequently lead to clinical disease in susceptible individuals (8,9). The elderly population generally also has the lower thermoregulatory capacity and relatively weak immunological defenses, which increases the vulnerability to respiratory tract infection due to hot and cold weather.

The biological plausibility underlying the gender difference have been explored. Previous studies indicated that men with pneumonia tend to be notably sicker than women with more compliances and worse vital signs (30). This may be explained by patterns of inflammatory, coagulation, and fibrinolysis biomarkers among men (31). Gender differences in immune system response to infection was also suggested, with investigations into the role of X chromosomes which encode genes for several important immune system mediators (32). In addition, smoking is associated with several diseases of the respiratory tract that predispose to infections, and activates a process that destroys the epithelium of the upper airways that eliminates the normal washout of potential pathogens (32). Higher smoking prevalence in male than in female (19.9% vs. 3.0% in 2010) in Hong Kong (33) may partly explain the vulnerability of men to cold exposure.

Higher attributable risk to cold temperature

The optimum temperature corresponding to the minimum geriatric pneumonia identified in HK was 25^{o}C, which was very close to the median temperature (24.7^{o}C) during the study period. Using the optimum as the reference, we calculated the overall disease burden of geriatric pneumonia attributed to temperature, and computed the components attributable to cold and heat that with temperature below or above the optimum. We followed the approach proposed by Gasparrini and Leone which accounted for the complex temporal patterns in exposure-lag-response relationships, and provided more appropriate estimations of attributable risk measures (25). The advantage of this approach was the provision of estimates for separate components of attributable risks from cold and hot temperatures, allowing extreme and moderate temperatures with different exposure ranges to be further examined. Most of the temperature-related geriatric pneumonia hospitalizations in Hong Kong was in fact attributable to cold, consistent with the exposure-response relationships and temperature distribution, as illustrated in Figure-2. Among the 10.7% of non-optimal temperature related emergency hospitalizations for geriatric pneumonia, 8.7% and 2.0% was due to cold and hot weather, inducing 17,102 and 3,981 cases, respectively. As for the overwhelming majority of the attributable risk occurred in the moderate temperature range in spite of its relatively low RRs, it may be explained that moderate temperature included the majority of the days in the series.

The limitations of this study should also be noted. Firstly, as in all other monitor-based time-series studies, personal exposure data were not available. The use of ambient temperature monitoring data to represent the population exposure may lead to exposure misclassifications. Hong Kong is a subtropical city with very high prevalence of air conditioning used in hot and humid summer but low prevalence of house heating used in temperate winter, the outdoor fixed-site measurement for ambient temperature may represent the average population exposure better in cool season than in hot season. Secondly, we only included emergency hospital admissions for pneumonia, which reflects the acute associations with environmental risk factors. However, the less severe cases were not captured. Therefore, the association with temperature examined in this study may not be applicable to the overall pneumonia incidence in elderly subjects. Finally, caution is warranted when the findings of this single-city study are generalized to other places with different climates and population characteristics.

In conclusion, we observed significant non-linear and delayed associations between both cold and hot temperatures and geriatric pneumonia. Cold temperatures exhibited much higher risk on the pneumonia incidence than hot temperatures. The majority of the temperature-related burden for pneumonia hospitalizations was attributed to cold weather. Results suggested elderly male had greater susceptibility to cold weather than female. This study will help informing public health policies in the planning of mitigation and intervention measures (such as central heating in winter) to prevent the adverse temperature-related pneumonia in vulnerable elderly population.

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Figure Legends:

Figure-1 Time-series plots of A) Daily mean temperature and emergency hospital admissions for pneumonia in B) the elderly population, for C) female and D) male subjects in Hong Kong during 2005-2012.

Figure-2 A) Association between cumulative temperature exposures over 0-21 lag days and emergency hospitalizations for pneumonia in the elderly, and B) Temperature distribution in Hong Kong during 2005-2012. 95% confidence intervals is indicated by the shaded areas. Three vertical dashed lines show the temperature at 1st percentile, the optimum of 25.0^{o}C, and the 99th percentile, respectively.

Figure-3 Association with cumulative temperature exposures over 0-21 lag days on emergency hospitalizations for pneumonia in the elderly population by gender in Hong Kong during 2005-2012, centering at 25.0^{o}C (dashed line). A): Total pneumonia; B): Elderly pneumonia; C): Elderly pneumonia in female; D): Elderly pneumonia in male.

TABLE 1 Descriptive statistics of daily emergency hospital admissions for pneumonia, weather conditions and air pollution concentrations in Hong Kong, 2005-2012 (2922 days)

Variables	Mean (SD)	Percentiles				
		Min.	25th	50th	75th	Max.
Daily emergency hospital admissions						
Total Pneumonia	91.5 (21.8)	42	76	88	103	184
Age <15	11.6 (6.1)	0	7	11	15	48
Age of 15~64	12.3 (4.9)	2	9	12	15	40
Age ≥ 65	67.5 (17.0)	24	55	65	77	135
Female	32.2 (9.5)	10	25	31	37	67
Male	35.4 (9.6)	12	29	34	41	78
Weather conditions						
Mean temperature (^{o}C)	23.4 (5.2)	8.7	19.1	24.7	27.9	31.8
Relative humidity (%)	78.4 (10.5)	31.0	74.0	79.0	85.8	99.0
Pollution concentration (μg/m^3)						
PM_{10}	50.5 (28.8)	7.6	28.2	45.1	68.1	573.0
NO_2	55.9 (19.3)	13.0	41.7	53.1	66.9	153.0
O_3	47.1 (30.2)	4.8	23.2	39.7	64.9	203.2

Abbreviations: SD-standard deviation; Min.-minimum; Max.-maximum; PM_{10}, particulate matter with aerodynamic diameter less than 10 μm; NO_2, nitrogen dioxide; O_3, ozone.

TABLE 2. Relative risk associated with cold and hot temperatures (RR with 95%CI) and emergency hospitalizations for pneumonia in the elderly population by gender over multiple lag days in Hong Kong, 2005-2012.

Disease Category and No. of Lag Days	Extreme Cold [a]		Moderate Cold [b]		Moderate Hot [c]		Extreme Hot [d]	
	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
Total Pneumonia								
0-1	0.79	0.76, 0.82	0.83	0.81, 0.86	1.09	1.06, 1.11	1.11	1.07, 1.15
2-6	1.20	1.15, 1.26	1.15	1.11, 1.20	0.97	0.95, 1.00	0.97	0.93, 1.01
7-21	1.48	1.37, 1.60	1.29	1.21, 1.38	1.05	1.01, 1.10	1.08	1.02, 1.15
0-21	1.41	1.27, 1.56	1.24	1.13, 1.36	1.11	1.05, 1.18	1.16	1.07, 1.26
Pneumonia in the Elderly (Age ≥ 65)								
0-1	0.80	0.76, 0.83	0.83	0.80, 0.86	1.11	1.07, 1.14	1.14	1.09, 1.18
2-6	1.31	1.24, 1.38	1.21	1.16, 1.27	0.96	0.93, 0.99	0.96	0.92, 1.00
7-21	1.54	1.41, 1.68	1.34	1.24, 1.44	1.02	0.97, 1.07	1.04	0.97, 1.11
0-21	1.61	1.43, 1.81	1.35	1.22, 1.49	1.08	1.01, 1.16	1.13	1.03, 1.23
Elderly Female								
0-1	0.77	0.73, 0.82	0.83	0.79, 0.87	1.12	1.08, 1.16	1.16	1.10, 1.22
2-6	1.30	1.21, 1.40	1.18	1.11, 1.26	0.94	0.90, 0.98	0.93	0.87, 0.98
7-21	1.35	1.19, 1.52	1.16	1.05, 1.29	1.01	0.94, 1.09	1.02	0.93, 1.12
0-21	1.35	1.15, 1.60	1.14	0.99, 1.31	1.07	0.97, 1.17	1.10	0.96, 1.25
Elderly Male								
0-1	0.82	0.77, 0.87	0.83	0.79, 0.87	1.09	1.05, 1.13	1.12	1.06, 1.18
2-6	1.32	1.23, 1.41	1.24	1.17, 1.32	0.98	0.94, 1.02	0.99	0.93, 1.04
7-21	1.74	1.55, 1.96	1.52	1.37, 1.68	1.02	0.95, 1.09	1.05	0.96, 1.15
0-21	1.89	1.61, 2.22	1.57	1.37, 1.80	1.10	1.00, 1.20	1.15	1.02, 1.31

Abbreviations: RR, relative risk; CI, confidence interval. a: The 1st percentile of temperature (11.2°C); b: The 10th percentile of temperature (15.8°C); c: The 90th percentile of temperature (29.4°C); d: The 99th percentile of temperature (30.6°C), all compared with the optimal temperature at 25.0°C.

TABLE 3. Attributable risk of temperature on emergency hospitalizations for pneumonia in the elderly by gender, contributing to overall, cold and hot temperature with 95% confidence intervals, 2005-2012.

Temperature	Total (*n* = 197,316)				Female (*n* = 93,964)				Male (*n* = 103,352)			
	AN [d]	95% CI	AF (%)	95% CI	AN [d]	95% CI	AF (%)	95% CI	AN [d]	95% CI	AF (%)	95% CI
Overall	21,058	15,554, 26,347	10.67	7.79, 13.47	5,340	1,065, 9,511	5.68	1.31, 9.86	15,224	11,394, 18,596	14.73	11.08, 18.18
Cold [a]	17,102	11,174, 22,510	8.67	5.40, 11.69	3,667	-973, 7,773	3.90	-1.08, 8.13	12,964	8,910, 16,554	12.54	8.86, 15.91
Extreme cold [b]	1,258	907, 1565	0.64	0.46, 0.81	424	180, 641	0.45	0.21, 0.69	822	593, 1,055	0.80	0.57, 1.01
Moderate cold [c]	15,964	9,468, 21,135	8.09	4.89, 10.73	3,224	-1,386, 7,293	3.43	-1.48, 7.55	12,304	8,761, 15,243	11.90	8.39, 15.38
Hot [a]	3,981	385, 7,527	2.02	-0.15, 3.78	1,681	-789, 4,048	1.79	-1.02, 4.02	2,276	-316, 4,638	2.20	-0.37, 4.53
Extreme hot [b]	168	34, 294	0.09	0.02, 0.15	65	-27, 148	0.07	-0.02, 0.16	103	15, 196	0.10	0.01, 0.18
Moderate hot [c]	3,801	140, 7,541	1.93	0.23, 3.71	1,607	-913, 3,791	1.71	-0.92, 3.94	2,169	-127, 4,561	2.10	-0.50, 4.36

Abbreviations: AN: attributable number; AF (%), attributable fraction (%); CI, confidence interval. a: Components attributable to cold and hot were computed with temperatures lower or higher than 25°C (the optimal), respectively; b: The extreme cold/hot was defined as the temperature lower than the 1st percentile or higher than the 99th percentile; c: the moderate cold/hot was defined as the temperature range between 1st/99th percentile and 25°C; d: The values in subgroups do not sum to the total, which is due to the approximation during calculation. The cumulative RRs over 0-21 days were used to compute the AN and AF (%).