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Reprint 977

The impact of cold and hot weather on senior citizens in Hong Kong

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Hong Kong Meteorological Society Bulletin, Volume 19 (2009),
August 2011

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The impact of cold and hot weather on senior citizens in Hong Kong

Abstract

The health impact of cold and hot weather on senior citizens in Hong Kong was studied based on the daily number of users who activated the Personal Emergency Link Service and who subsequently required hospitalization. The study reveals that the health of senior citizens in Hong Kong is affected by both cold and hot weather. They are more vulnerable to low temperatures in cool seasons than high temperatures in hot seasons. Relative humidity is another factor influencing the health impact of the hot/cold weather. Senior citizens face higher health risk in dry conditions on Cold Days (with daily minimum temperatures ≦ 12.0 °C). The health risk is lower in dry conditions on Hot Nights (with daily minimum temperatures ≧ 28.0 °C).

KEY WORDS: senior citizens; Personal Emergency Link Service; hospitalization; Hong Kong

1. Introduction

Hong Kong, located at the coast of southern China (22.3°N, 114.2°E), has a monsoonal climate. Winter in Hong Kong (December, January and February) sometimes has cold days with daily minimum temperatures below 10°C. Spells of high humidity occur occasionally in March and April. May to August is hot and humid with afternoon temperatures often exceeding 31°C. According to the 30-year (1971-2000) climatological normals, there are about 19 Cold Days (daily minimum temperatures ≦ 12.0 °C), 13 Hot Nights (daily minimum temperatures ≧ 28.0 °C) and 10 Very Hot Days (daily maximum temperatures ≧ 33.0 °C) annually in Hong Kong (Lee *et al*, 2007).

The health impact of cold and hot weather on human populations has been widely studied (Alberdi *et al*, 1998; Keatinge *et al*, 1995; Kunst *et al*, 1993). In Hong Kong, Leung *et al* (2008) found that the mortality rate would increase in hotter weather in summer and in colder weather in winter. While mortality has been commonly used as an indicator in studies on weather related health risks, it cannot truly reflect the health impact of weather as death is a rare event which may be caused by many factors other than weather. A less "restrictive" indicator would be desirable to represent health impacts on senior citizens in Hong Kong in cold and hot weather. This study used the daily number of users of the Personal Emergency Link Service who called for the Service and who subsequently required hospitalization as recorded by the Hong Kong Senior Citizen Home Safety Association (the Association) as such an indicator.

The Association is a non-governmental organization. It operates the 24-hour emergency support and care service, the

Personal Emergency Link Service (PE-Link Service) for senior citizens in Hong Kong. The details of the PE-Link Service are described in Appendix I. It has been observed that both the daily number of calls for the PE-Link Service and the daily number of callers who subsequently require hospitalization are higher in cold and hot weather compared with normal times. Of these two types of daily numbers, the daily number of callers eventually requiring hospitalization was chosen as an indicator of health impact for this study because some of the calls are not health related, e.g. requests for information and appeals to settle family disputes. On the other hand, the daily number of callers eventually requiring hospitalization is a more specific measure representing real impact experienced by senior citizens in Hong Kong. This study explored the relationship between the daily number of users making PE-Link calls requiring subsequent hospitalization and the ambient air temperature and other meteorological parameters.

2. The Data Set

As at 31 December 2008, the PE-Link Service was serving 63,505 active users. Among the 63,505 active service users, about 70% of them were senior citizens aged 75 or above and more than 90% of them suffered from one or more chronic diseases. In this study, the PE-Link Service users were taken as representative of the more vulnerable senior citizens in Hong Kong.

The daily numbers of PE-Link Service users who called for the Service and required subsequent hospitalization recorded by the Association in the period from 1 January 2004 to 31 December 2008 were used for this study. The number of users increased from 29,397 on 1 January 2004 to 63,505 on 31 December 2008. To facilitate comparison and analysis, the daily numbers were normalized to a population of 50,000 PE- Link Service users. The normalized daily number of users who called for the Service and required subsequent hospitalization is denoted as *PE*.

Air temperature, relative humidity and wind speed together constitute the thermal stress to human beings (Li *et al*, 2000). As the PE-Link Service users remain indoors when they request the service, the effect of wind speed on *PE* would be minimal. It is therefore not be included in this study. Furthermore, as the daily mean temperature can hide significant patterns in temperature variations at the two extremes of the temperature scale, the effects of daily maximum and minimum temperatures instead of daily mean temperatures are analysed.

The daily maximum temperature (T_{max}), daily minimum temperature (T_{min}) and daily mean relative humidity (*RH*) recorded at the Hong Kong Observatory Headquarters from 1 January 2004 to 31 December 2008 were used for analysis. During the period, there were 103 Cold Days ($T_{min} \leqq 12.0\,^{\circ}$C), 98 hot nights ($T_{min} \geqq 28.0\,^{\circ}$C) and 61 Very Hot Days ($T_{max} \geqq 33.0\,^{\circ}$C). The lowest T_{min} was 6.4 °C recorded on 1 January 2005 and the highest T_{max} was 35.4 °C recorded on 19 July 2005.

3. Analysis and Results

3.1. Seasonality of PE

In the period from 1 January 2004 to 31 December 2008 (the study period, a total of 1,827 days), the total normalized number of PE Link Service callers requiring hospitalization was 132,797 with a normalized daily average of 72.7±11.9. Table 2-1 shows the average *PE* for the 765 days in the hot seasons (May to September) and for the 1,062 days in the cool seasons (October to April) in the study period.

The t-test (Wilks, 1995) was conducted to examine whether the average *PE* for the 1,062 days in the cool seasons was significantly different from that for the 765 days in the hot seasons in the study period from 1 January 2004 to 31 December 2008. The t-test results

Table 2-I. Statistics on the average daily number of callers requiring hospitalization in the hot seasons (May to September) and cool seasons (October to April) in the period from 1 January 2004 to 31 December 2008. The figures are normalized to a population of 50,000 PE-Link Service users.

Period	Average (callers/day)	Standard Deviation (callers/day)
Whole study period	72.7	11.9
Hot season	71.1	10.9
Cool season	73.8	12.5

indicated that the difference was significant at the 5% level (p-value $=5.22\text{x}10^{-7}$). Thus, in the study period there were on average more callers requiring hospitalization on days in the cool seasons than in the hot seasons. In broader terms, senior citizens in Hong Kong were at higher health risk in the cool season than in the hot season.

3.2. *Variation of PE with respect to T_{max}*

Denoting the total number of days in the study period with T_{max} in the range $|T_{max}|$ to $|T_{max}| + 1.9$ °C by n, the average *PE* of these n days, denoted as $PE(T_{max})$, was obtained by dividing the sum of the *PE* for these n days by n. The choice of the 2°C increment was to increase the statistics of the number of calls made within the temperature range.

Figure 2-1 shows the variation of $PE(T_{max})$ with respect to T_{max}. The standard errors for $PE(T_{max})$ were also shown in the figure to illustrate the variation of $PE(T_{max})$ in the respective T_{max} range. It shows that $PE(T_{max})$ has a U-shape relationship with T_{max} with a minimum of about 70.0 callers/day for 28.0 °C $\leqq T_{max} \leqq$ 29.9 °C. The t-test results show that the $PE(T_{max})$s for 26.0 °C $\leqq T_{max} \leqq$ 27.9 °C (p-value=0.134) and 30.0°C $\leqq T_{max} \leqq$ 31.9 °C (p-value=0.092) were insignificantly different from that for 28.0 °C $\leqq T_{max} \leqq$ 29.9 °C at the 5% level. The value of 70.0 callers/day could be regarded as the baseline level for $PE(T_{max})$ which apparently did not vary for 26.0 °C $\leqq T_{max} \leqq$ 31.9 °C. This reveals that the health status of senior citizens in Hong Kong was apparently not affected by variation of T_{max} within this range of T_{max}. This range of T_{max} (26.0 °C to 31.9 °C) could be regarded as the homeostasis range of T_{max} for senior citizens in Hong Kong.

For T_{max} outside the homeostasis range, $PE(T_{max})$ increased with increasing T_{max} for $T_{max} \geqq$ 32.0 °C, and increased with decreasing T_{max} for $T_{max} <$ 26.0 °C. The $PE(T_{max})$ was higher than the baseline level (70.0 callers/day) by about 7% for 34.0 °C $\leqq T_{max} \leqq$ 35.9 °C and by more than 9% for $T_{max} <$ 18.0 °C.

3.3. *Variation of PE with respect to T_{min}*

Similar to $PE(T_{max})$, $PE(T_{min})$ was defined as the average *PE* for those days with T_{min} in the range $|T_{min}|$ to $|T_{min}| + 1.9$ °C.

The variation of $PE(T_{min})$ with respect to T_{min} (Figure 2-2) shows a similar pattern to that of $PE(T_{max})$. It had a minimum of about 70.0 callers/day for 24.0 °C $\leqq T_{min} \leqq$ 25.9 °C. The t-test results showed that the $PE(T_{min})$s for 20.0 °C $\leqq T_{min} \leqq$ 21.9 °C (p-value=0.056), 22.0 °C

$\leqq T_{min} \leqq 23.9$ °C (p-value=0.341) and 26.0 °C $\leqq T_{min} \leqq 27.9$ °C (p-value=0.102) were insignificantly different from that for 24.0 °C $\leqq T_{min} \leqq 25.9$ °C at the 5% level.

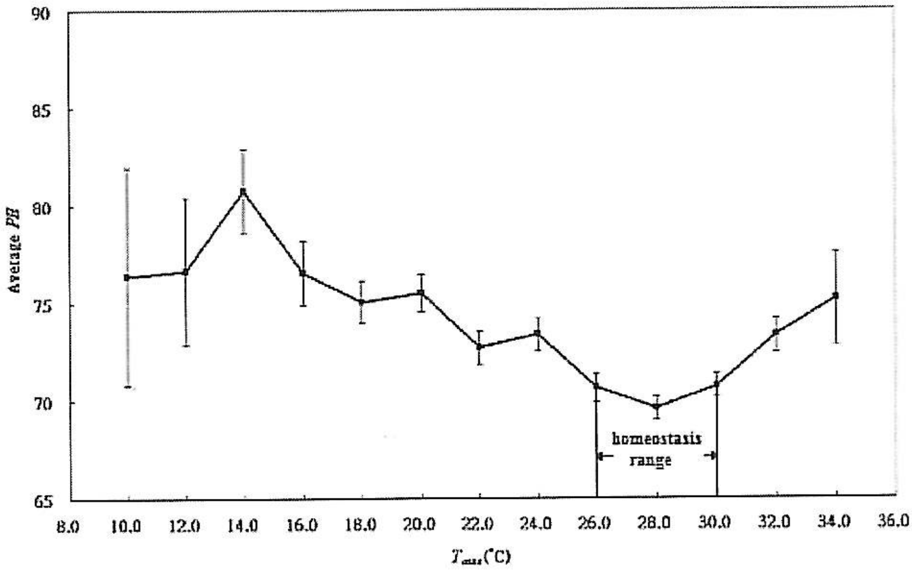

Figure 2-1 Variation of the average normalized daily number of PE-Link Service callers who required subsequent hospitalization (PE) at different ranges of daily maximum temperature (T_{max}) at 2 °C intervals. The t-test results showed that the values of average PE for T_{max} of 26.0 °C to 27.9 °C, 28.0 °C to 29.9 °C and 30.0 °C to 31.9 °C were statistically not different from each other.

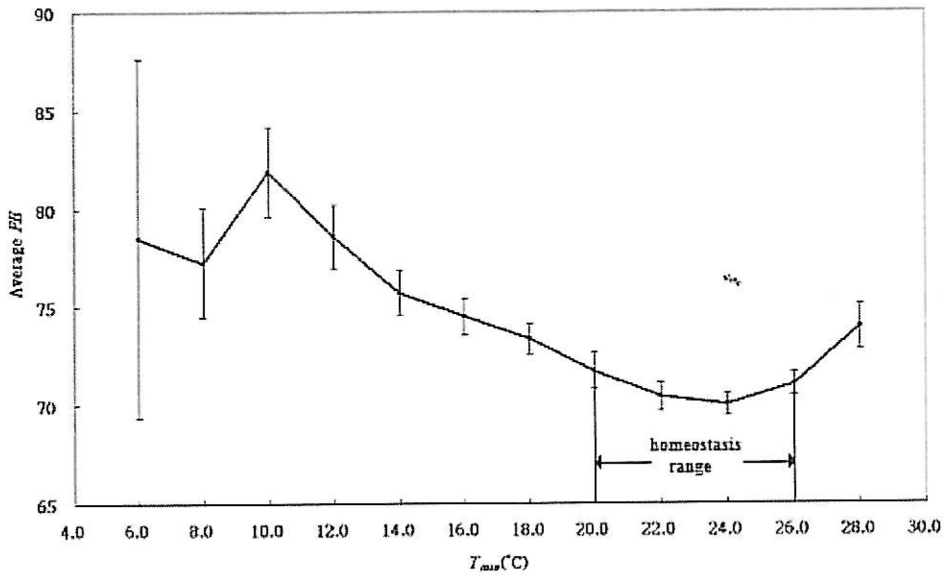

Figure 2-2. Variation of the average normalized daily number of PE-Link Service callers who required subsequent hospitalization (PE) at different ranges of daily minimum temperature (T_{min}) at 2 °C intervals. The t-test results showed that the values of PE for T_{min} of 20.0 °C to 21.9 °C, 22.0 °C to 23.9 °C, 24.0 °C to 25.9 °C and 26.0 °C to 27.9 °C were statistically not different from each other.

(to be continued on P. 26)

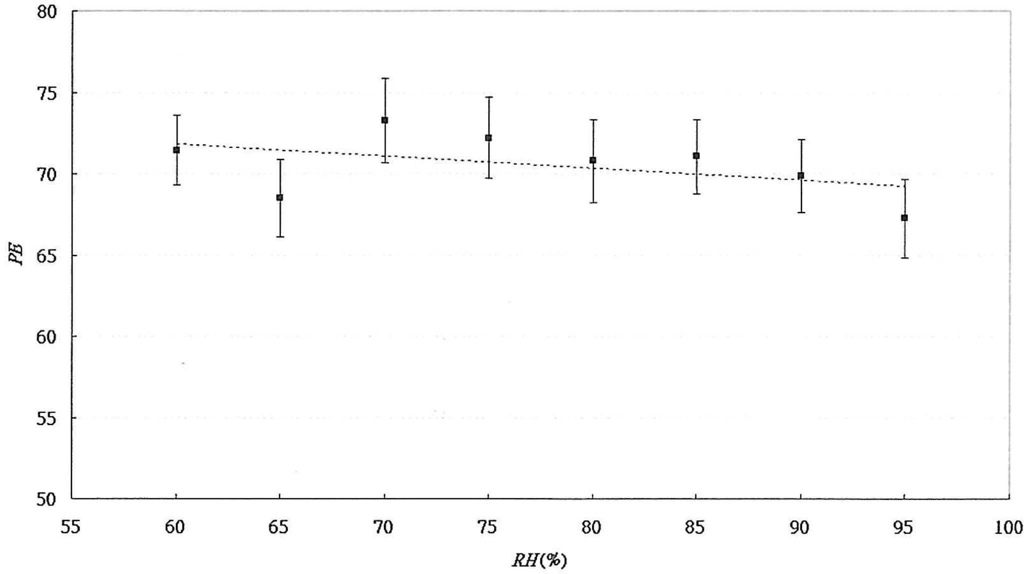

Figure 2-3 *Variation of the average normalized daily number of PE-Link Service callers who required subsequent hospitalization (PE) at different ranges of daily average relative humidity (RH) at 5% intervals in the hot season (May to September). The dotted line shows the best linear fit with a correlation coefficient R^2 of 0.21*

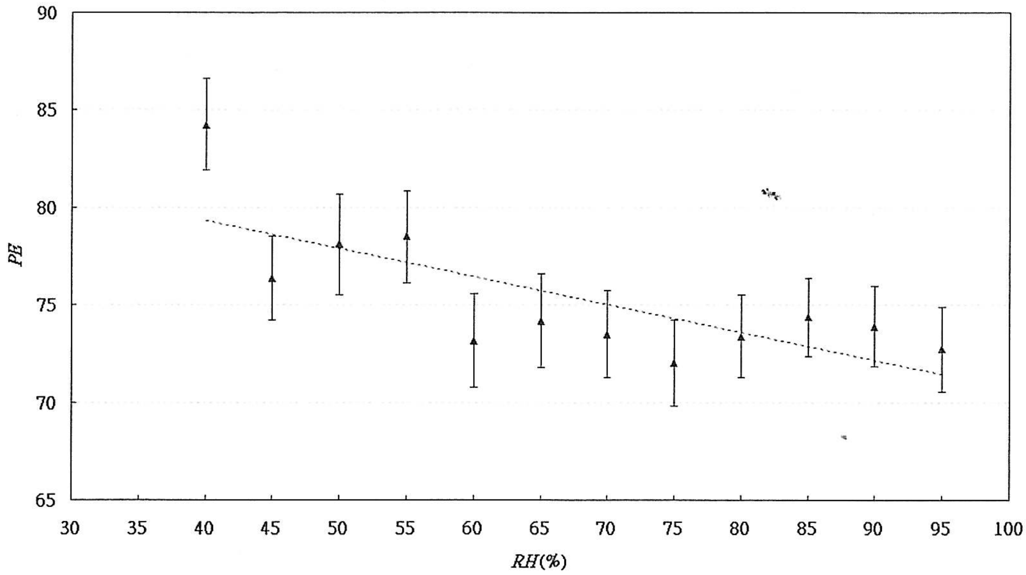

Figure 2-4. Variation of the average normalized daily number of PE-Link Service callers who required subsequent hospitalization (PE) at different ranges of daily average relative humidity (RH) at 5% intervals in the cool season (October to April). The dotted line shows the best linear fit with a correlation coefficient R^2 of 0.55.

This range (20.0 °C to 27.9 °C) could be regarded as the homeostasis range of T_{min} for senior citizens in Hong Kong.

At higher T_{min}, $PE(T_{min})$ exceeded the baseline value by more than 5% for hot nights with $T_{min} \geqq 28.0$ °C. On the low temperature end, $PE(T_{min})$ increased with decreasing T_{min} for $T_{min} < 20.0$ °C. It exceeded the baseline value by more than 10% for $T_{min} < 14.0$°C.

3.4. *Variation of PE with respect to RH*

Similar to $PE(T_{max})$ and $PE(T_{min})$, $PE(RH)$ was defined as the average *PE* for those days with *RH* in the range $|RH|$ to $|RH| + 4.9\%$. The choice of the 5% increment was to increase the statistics of the number of calls made within the *RH* range.

Figure 2-3 and 2-4 (on P. 25) show the variations of *PE* with respect to *RH* at 5% intervals in the cool and hot seasons respectively. Data points with frequency of occurrence less than 10 (i.e. on average less than two days per year in the study period) were not plotted.

In the hot seasons, the *PE* increased with decreasing *RH* but the trend was statistically insignificant. It reveals that variation of relative humidity apparently has insignificant impact to senior citizens in Hong Kong in hot seasons. In the cool seasons, the *PE* increased with decreasing *RH* with a statistically significant trend. The *PE* was higher at drier conditions for relative humidity lower than 60%. It reveals that senior citizens in Hong Kong are more vulnerable in drier conditions in the cool seasons.

3.5. *Probability of days with high PE*

The probability of days with high *PE* (denoted as *PE(H)* day) at different T_{min} (or T_{max}) and *RH* domains was also studied. *PE(H)* day is defined as the days with *PE* higher than the mean daily value by more than one standard deviation. The probability of *PE(H)* day for a specific T_{min} (or T_{max}) and *RH* domain can be determined by the percentage of the number of *PE(H)* days among all the days in the domain. As the average *PE* in the hot and cool seasons were statistically different from each other (Table 2-1), the probabilities of high *PE(H)* days in the two seasons were analysed separately.

To examine the effect of *RH* on the probability of *PE(H)* day, the *RH* was categorized into three domains in this study with $RH \leqq 70\%$, $70\% < RH < 85\%$, and $RH \geqq 85\%$ corresponding to "dry", "normal" and "humid" conditions in Hong Kong respectively.

3.5.1. *Variation of the probability of PE(H) day with T_{max} and RH in the hot season*

As the average *PE* in the hot season in the study period was 71.1 ± 10.9 callers/day (Table 2-1), those days with $PE > 82.0$ callers/day were regarded as *PE(H)* days in the hot season. Figure 2-5 shows the variation of the probability of *PE(H)* day for T_{max} higher than or equal to specified values at a 2°C increment in the hot season. It was noted that the probability of *PE(H)* day for $T_{max} \geqq 28.0$ °C was about 15% and started to increase at higher T_{max}. The probability for $T_{max} \geqq 34.0$ °C was about 25%.

The probabilities of *PE(H)* day at different T_{max} and *RH* domains in the hot season in the study period are summarized in Table 2-2. The number in the bracket of each domain is the number of days with the specific T_{max} and *RH* in the study period. The probabilities of *PE(H)* day for all *RH* and all T_{max} in their respective ranges are shown in the last row and right-most column of the table respectively.

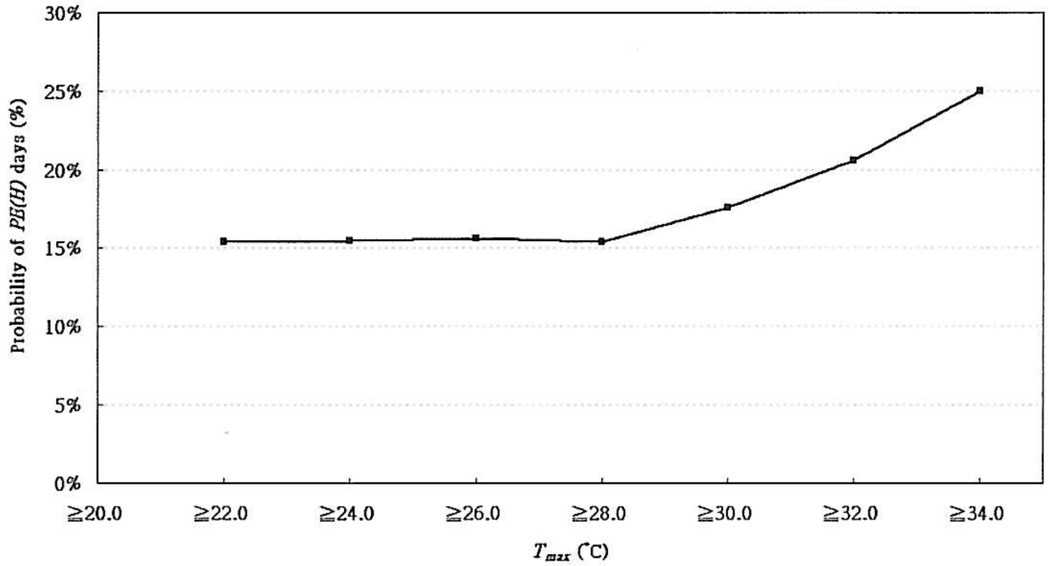

Figure 2-5 Variation of the probability of occurrence of high normalized daily number of PE-Link Service callers who required subsequent hospitalization (PE(H) day) for daily maximum temperature (T_{max}) higher than or equal to specified values in the hot season.

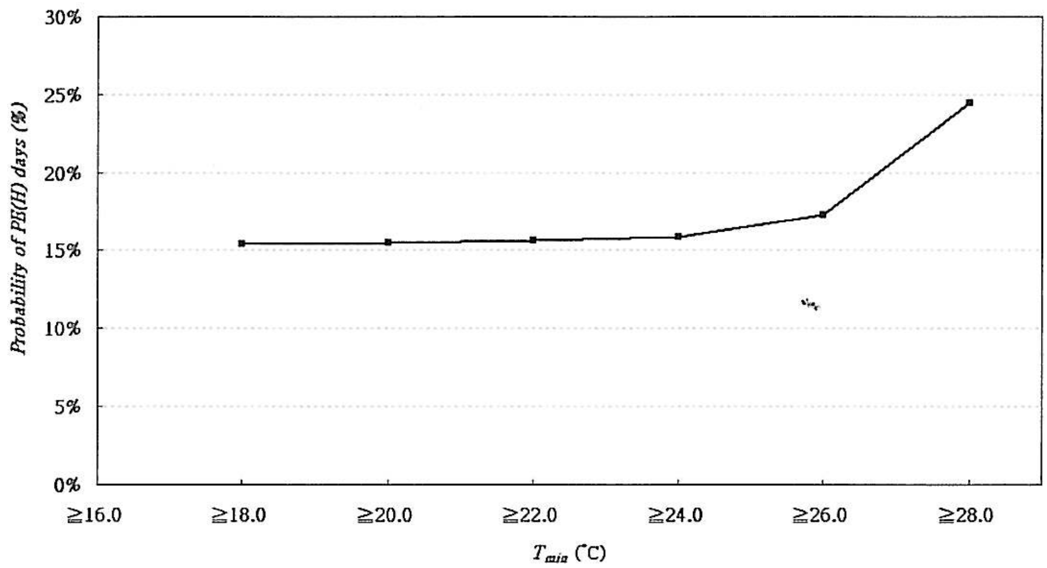

Figure 2-6. Variation of the probability of occurrence of high normalized daily number of PE-Link Service callers who required subsequent hospitalization (PE(H) day) for daily minimum temperature (T_{min}) higher than or equal to specified values in the hot season.

Table 2-2. The probabilities of occurrence of high normalized daily number of PE-Link Service callers who required subsequent hospitalization (PE(H) day) for different daily maximum temperature (T_{max}) and daily average relative humidity (RH) in the hot season (May to September). The numbers in bracket are the number of days with the specific T_{max} and RH in the study period.

T_{max} (°C)	*RH*			
	RH≦70%	70% <*RH* <85%	*RH*≧85%	All *RH* range
<28.0	0% (2)	19% (26)	15% (94)	16% (122)
28.0≦T_{max}<33.0	13% (39)	17% (384)	11% (159)	15% (582)
≧33.0	0% (6)	20% (55)	- (0)	18% (61)
All T_{max} range	11% (47)	17% (465)	13% (253)	15% (765)

Table 2-3. The probabilities of occurrence of high normalized daily number of PE-Link Service callers who required subsequent hospitalization (PE(H) day) for different daily minimum temperature (T_{min}) and daily average relative humidity (RH) in the hot season (May to September). The numbers in bracket are the number of days with the specific T_{min} and RH in the study period.

T_{min} (°C)	*RH*			
	RH≦70%	70% <*RH* <85%	*RH*≧85%	All *RH* range
<23.0	29 (7)	5% (19)	16% (25)	14% (51)
23.0≦T_{min}<28.0	9% (33)	16% (356)	12% (227)	14% (616)
≧28.0	0% (7)	27% (90)	0% (1)	24% (98)
All T_{min} range	11% (47)	17% (465)	13% (253)	15% (765)

It was noted that there was no "humid" Very Hot Days in the study period. The probability of *PE(H)* days for the "normal" Very Hot Days was 20% and there was no *PE(H)* day in the 6 "dry" Very Hot Days. A t-test for the significance of the difference in the probabilities of high *PE(H)* days for these two *RH* ranges was conducted. The difference was insignificant at the 5% level (p-value= 0.115). This indicated that the health risk of senior citizens in Hong Kong were not significantly higher in high relative humidity on Very Hot Days.

3.5.2 Variation of the probability of PE(H) day with T_{min} and RH in the hot season

Figure 2-6 shows the variation of the probability of *PE(H)* day for T_{min} higher than or equal to specified values at a 2°C increment in the hot season. It was noted that the probability for T_{min} ≧ 24.0°C was about 15% and started to increase at higher T_{min}. The probability for T_{min} ≧ 28.0°C was about 25%.

Table 2-3 summarizes the probabilities of *PE(H)* day at different T_{min} and *RH* domains in the hot season. The probabilities of *PE(H)* day for all *RH* and all T_{min} in their respective ranges are shown in the last row and right-most column of the table respectively. There was only one "humid" Hot Night in the study period. For the other two categories of *RH*, the probability of *PE(H)* day for the "normal" Hot Nights was 27% whereas there was no *PE(H)* day in the 7 "dry" Hot Nights. A t-test was conducted for the significance of the difference between the two probabilities. The difference was marginally insignificant at the 5% level but significant at the 10% level (p-value=0.058). This indicated that senior citizens in Hong Kong were less vulnerable on "dry" Hot Nights than on 'normal' Hot Nights.

3.5.3. *Variation of the probability of PE(H) day with T_{min} and RH in the cool season*

As the average *PE* in the cool season in the study period was 73.8±12.5 callers/day (Table 2-1), those days with $PE > 86.3$ callers/day were regarded as *PE(H)* days in the cool season. Figure 2-7 shows the variation of the probability of *PE(H)* day for T_{min} lower than or equal to specified values at 2°C increment in the cool season. The probability of *PE(H)* day for $T_{min} \leqq 24.0$ °C was about 15% and started to increase with decreasing T_{min}. The probability for $T_{min} \leqq 8.0$ °C was about 43%.

Table 2-4 summarizes the probabilities of *PE(H)* day for different T_{min} and *RH* domains in the cool seasons in the study period. The probability of *PE(H)* day was 38% for Cold Days. The probabilities of *PE(H)* day for all *RH* and all T_{min} in their respective ranges are shown in the last row and right-most column of the table respectively. Comparing the probability of *PE(H)* day for Cold Days with those for Very Hot Days and Hot Nights in Table 2-2 and Table 2-3 respectively, the t-test results showed that the probability of *PE(H)* day on Cold Days were higher than that on Very Hot Days (p-value:0.004) and that on Hot Nights (p-value:0.021) at the 5% level. This revealed that senior citizens in Hong Kong were at higher health risk on Cold Days in the cool season than on Hot Nights and Very Hot Days in the hot season. Availability of air-conditioning practically everywhere in summer and lack of central heating in most places in winter in Hong Kong might be the major reason for the observed phenomena.

The probabilities of *PE(H)* day for "dry", "normal" and "humid" Cold Days were 46%, 23% and 32% respectively. The t-test results showed that the probability of high *PE(H)* day for "dry" Cold Days was significantly higher than that for "normal" Cold Days (p-value:0.029) but insignificantly different from that for "humid" Cold Days (p-value:0.129) at the 5% level. On the other hand, the probability of high *PE(H)* day for "humid" Cold Days was insignificantly different from that for "normal" Cold Days (p-value:0.251).

There were a total of 44 "normal" and "humid" Cold Days in the study period. The probability of high *PE(H)* day for these 44 Cold Days was about 27% which was significantly lower than that for the 59 "dry" Cold Days at the 5% level (p-value:0.020). The results showed that senior citizens in Hong Kong were more vulnerable to dry conditions on Cold Days in terms of health.

4. Conclusion

The health of senior citizens in Hong Kong was affected by both cold and hot weather. They were at higher health risks in cold than in hot weather. They were more vulnerable on Cold Days in the cool season than Hot Nights and Very Hot Days in the hot season. Relative humidity was another factor influencing the health impact of cold and hot weather. It could enhance or reduce the effect of temperature to the health of senior citizens in Hong Kong. In the hot season, senior citizens in Hong Kong were less vulnerable on "dry" Hot Nights than Hot Nights with higher relative humidity. On the other hand, they were more vulnerable on "dry" Cold Days than Cold Days with higher relative humidity in the cool season.

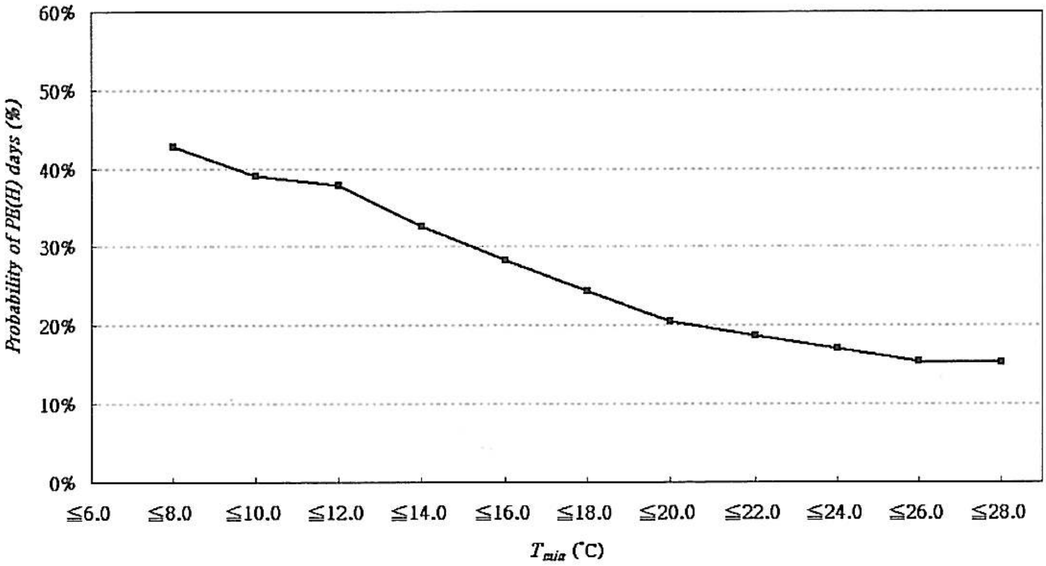

Figure 2-7 Variation of the probability of occurrence of high normalized daily number of PE-Link Service callers who required subsequent hospitalization (PE(H) day) for daily minimum temperature (T_{min}) lower than or equal to specified values in the cool season.

Table 2-4 The probabilities of occurrence of high normalized daily number of PE-Link Service callers who required subsequent hospitalization (PE(H) day) for different daily minimum temperatures (T_{min}) and daily average relative humidity (RH) in the cool season (October to April). The numbers in bracket are the number of days with the specific T_{min} and RH in the study period.

T_{min} (°C)	*RH*			
	RH≦70%	70% <*RH* <85%	*RH*≧85%	All *RH* range
≦12.0	46% (59)	23% (22)	32% (22)	38% (103)
12.0< T_{min}≦17.0	24% (103)	22% (125)	15% (53)	21% (281)
>17.0	10% (134)	8% (379)	12% (165)	9% (678)
All T_{min} range	22% (296)	12% (526)	15% (240)	15% (1062)

Appendix I

Personal Emergency Link Service (PE-Link Service)

The PE-Link Service started operation in 1996. It operates on the PE-Link System which consists of two parts, the main unit connecting to the fixed phone line at users' home and a remote trigger. It operates through integrated communication system which enables duplex voice communication. Whenever the service users require assistance, they can simply press the one-touch button on the remote trigger. Signal will then be sent to the main unit of the PE-Link System via radio frequency and it will dial a phone call to the Association's 24-hour operating call centre. Services using similar technology have been rendered in other countries such as USA, Canada, Australia, UK, North America, etc. (De San Miguel *et al*, 2008; Dibner, 1992). After receiving the call, operators will communicate with the service users through the full duplex voice communication of the device, identify their needs and assess the situation. The operators will provide timely assistance according to the previously agreed protocol, such as informing the users' emergency contact persons or sending users with illnesses to the public hospitals. If the operators do not receive any voice response from the users within 2 minutes after their emergency calling, the operators will treat the case as an emergency and send for the Fire Service to undertake rescue accordingly. As at 31 December 2008, the Association has rendered 24-hour timely care to more than 120,835 service users in Hong Kong in the past 12 years. Over the past 12 years, the Association received 3,056,461 calls, of which 173,927 calls required timely medical assistance.

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