The relationship of ambient temperature and humidity with mortality on the Maltese Islands 1992-2005

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Key messages

- Daily mortality rates during winter are higher than during the remaining seasons - this difference is more conspicuous in persons aged 65 years and over;
- The optimum average apparent temperature during which mortality rate was at a minimum was found to be around 27°C;
- Mean average apparent temperature during winter during the period 1992-2005 was 11.57ºC and average daily mortality rate during this season was 18.07/100000 in persons over 65 years and 0.64/100000 in persons under 65 years. During the summer the mean average apparent temperature was 29.93ºC and the average daily mortality rate during this season was 12.46/100000 in persons over 65 years and 0.57/100000 in persons under 65 years.
- At temperatures above 27ºC the daily mortality rate increases more rapidly per degree compared to when it drops below 27ºC;

There exists a relationship between ambient temperature and mortality. In healthy individuals, an efficient heat regulation system enables the body to cope effectively with thermal stress *[1]*. However, in susceptible individuals, when temperatures exceed a certain limit, winter cold spells and summer heat waves result in an increase in the number of deaths. Heat and cold related deaths are often subject to misclassification and rarely coded as death being caused directly by heat or cold. Persons with pre-existing medical conditions are more susceptible to death during extremes of temperature and commonly cardiovascular, respiratory and other causes of death are reported as underlying cause of death. Therefore total mortality or cause-specific mortality is often used to study the effect of temperature on mortality.

Interactions between climate and health are location-specific *[2]*. The minimum mortality temperature (i.e. the inflection point of the U-shaped curve), defined as the temperature of the lowest temperature-associated mortality in a city, was shown to vary by latitude *[3, 4]*. Specific local studies are required to assess the impact of temperature on the locality. The optimum or threshold temperature varies between populations and is assumed to be a function of the population adaptation to local climate. That is, the warmer the climate, the higher the threshold temperature above which heat related mortality is detectable *[5]*.

This chapter will describe the effect of ambient temperature and humidity on mortality in the Maltese population during winter and summer months with particular attention to different age groups. Different trends in mortality in winter and summer months will be illustrated.

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Method

In this study a time-series analysis approach was used. The time-series study generally encompasses large populations in multiple geographic areas over a given time period. Mortality counts or rates are compared to exposure measurements collected at regular time intervals (e.g., daily, weekly).

Exposure to ambient temperature is often defined as some combined metric of temperature and relative humidity or dew point temperature, such as heat index, humidex, or apparent temperature, depending on the study location. In this study we used daily maximum and minimum relative humidity data was also provided for the period 1st January 1992 to 31st December 2005. Average daily temperatures and average daily humidity were calculated for the whole study period and then used to calculate average apparent temperature. The Meteorological Office of the Malta International Airport provided daily maximum and minimum temperatures.

We investigated all-cause mortality. Data on daily deaths among residents of the Maltese Islands were collected from the Malta National Mortality Registry from 1st January 1992 to 31st December 2005. Age specific daily mortality rates were calculated for persons aged over and less than 65 years. Daily mortality rates (per 100,000) were analyzed using a generalized estimating equations (GEE) model. To allow for skewness in the daily mortality rate distribution the model assumed a Gamma distribution and an identity link function. An auto regressive correlation structure with lag one was used since it was evident that correlations decrease as distance between observations increases. Several predictors, including apparent temperature, season and year when death occurred and age of the deceased person, were included in the model fit to explain variations in the daily mortality rates. To allow for the delayed effect of apparent temperature on mortality rates, the maximum average apparent temperature of current and previous 3 days (lag 0–3) was chosen for the warm season; while the minimum average apparent temperature of current and previous 15 days (lag 0–15) was chosen for the cold season. The current apparent temperatures in autumn and spring were retained. To allow for a different increase in mortality rates at very low and very high apparent temperatures a cubic function was assumed for apparent temperature.

Results

41012 deaths in residents of the Maltese Islands over 5108 days were collected. The average number of daily deaths over the whole period was 8.03. The average temperature over this period was 19.35°C (average apparent temperature = 19.32ºC). Over this period, the minimum temperature recorded was 6.2°C (minimum average apparent temperature = 3.68ºC) while the maximum temperature was 35.5°C (maximum average apparent temperature = 38.09ºC).

Over the whole study period the coldest months i.e. January and February accounted for the largest number of deaths. October, with an average temperature of 21.6°C (average apparent temperature of 23.7ºC) accounted for the least number of deaths. A small increase in the number of deaths also occurred during the summer months July and August (Fig. 1).

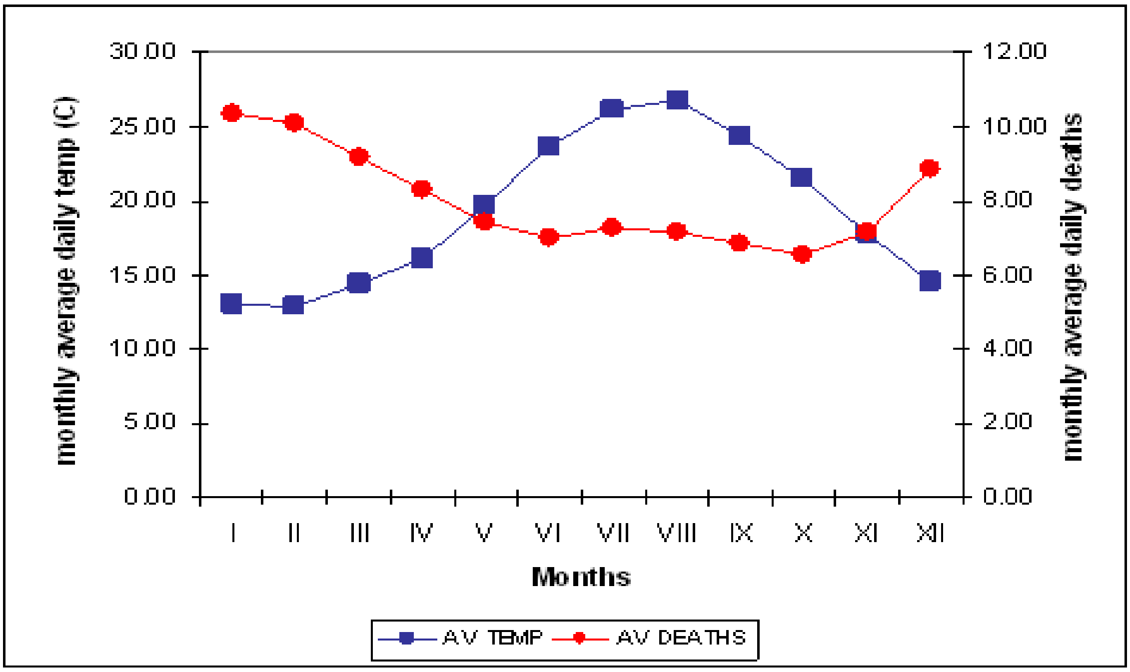

Fig. 1: Distribution of monthly average daily number of deaths from all causes as well as monthly average daily temperature over the period 1992-2005

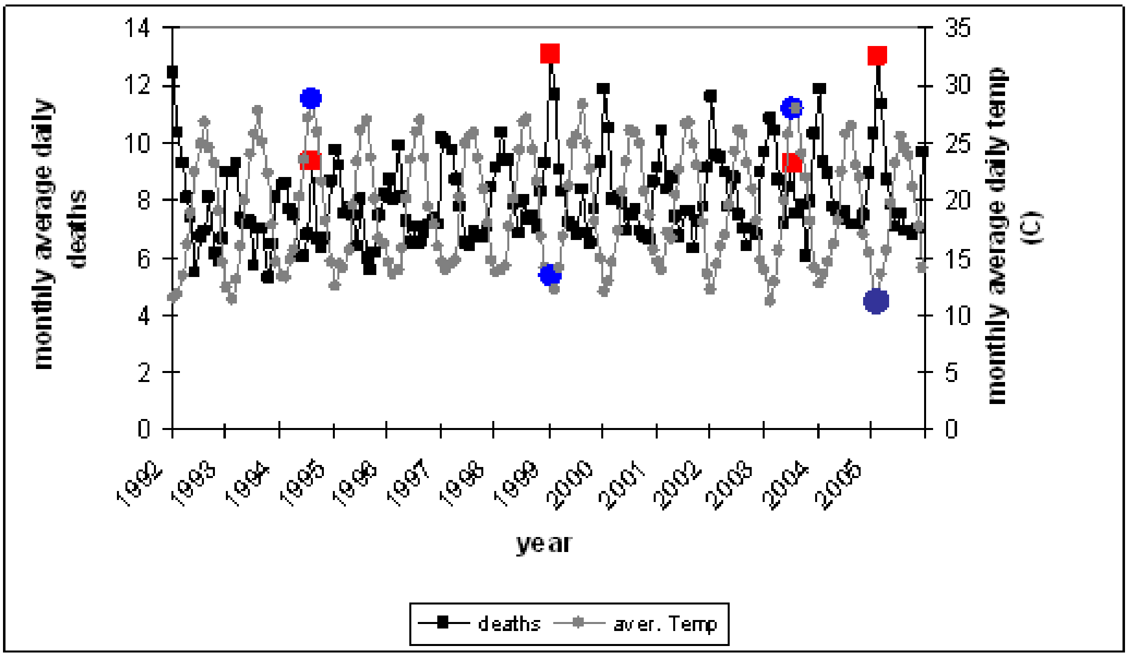

Fig. 2: Monthly average daily deaths and monthly average daily temperature over the period 1992-2005

Daily death rates peak in the winter months. The highest peak in daily deaths occurred during January 1999 (average monthly daily deaths: 13.1, average temperature: 13.4°C, average apparent temperature: 11.49ºC) and February 2005 (average monthly daily deaths: 13.1, average temperature: 11.1°C, average apparent temperature: 8.14ºC). The highest peak number of deaths during the summer months occurred during August 1994 (average monthly daily deaths: 9.4, average temperature: 28.8°C, average apparent temperature 33.27ºC) and July 2003 (average monthly daily deaths: 9.3, average temperature: 28.0°C, average apparent temperature 32.53ºC) (Fig. 2).

Over the period 1992-2005 the overall average mortality rate of those aged 65 years and over has decreased over the years. This decrease is also seen by season especially in he winter months which experienced the greatest number of deaths (Fig. 3).

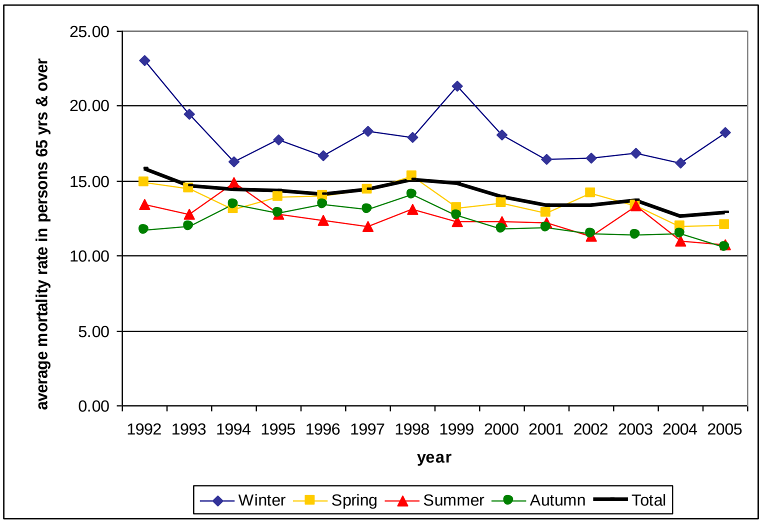

Fig. 3: Average mortality rate/100000 per season over the years 1992-2005 in persons aged 65 yrs and over

Daily mortality rates during winter are higher than daily mortality rates during the remaining seasons; however, this difference is more conspicuous for persons aged at least 65 years (Figs. 4, 5) and is consistent with trends in other European countries.

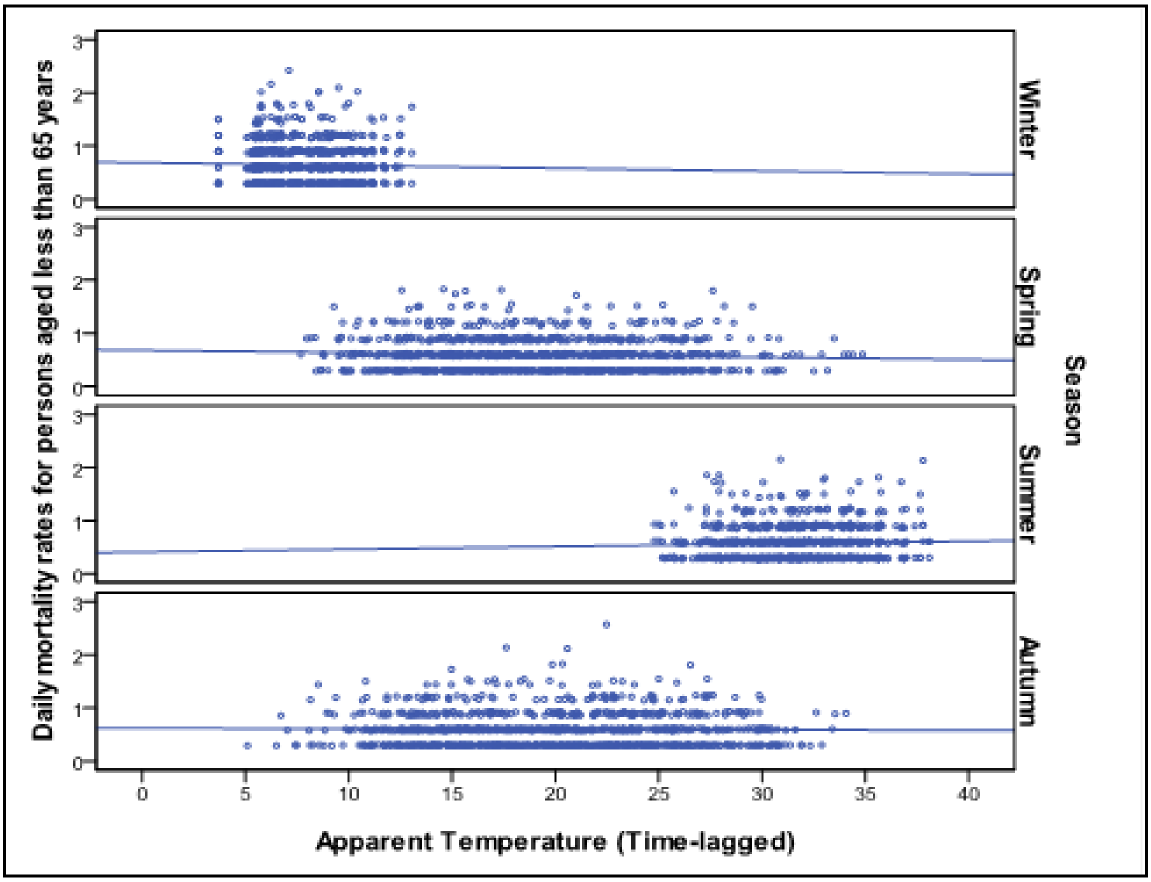

Fig. 4: Daily mortality rate for persons less than 65 years by apparent temperature and season

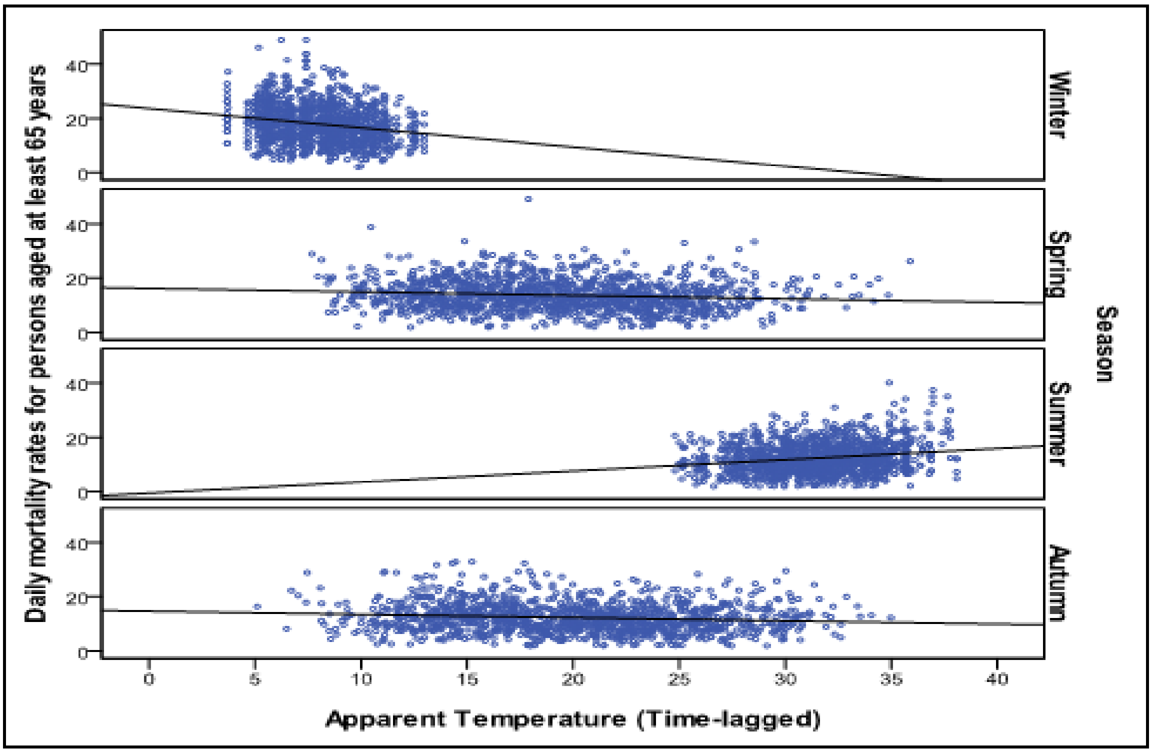

Fig. 5: Daily mortality rate for persons aged 65 years and over by apparent temperature and season

A cubic function relating mortality rates of persons aged at least 65 years and apparent temperature was used on the merit that this provided a minimum mortality rate and different slopes at both ends of the apparent temperature scale. The optimum average apparent temperature in which daily mortality rate was at a minimum was found to be around 27°C for persons aged 65 years and over. The cubic relationship between mortality rates and apparent temperature is much weaker for deaths under 65 years (Fig. 6).

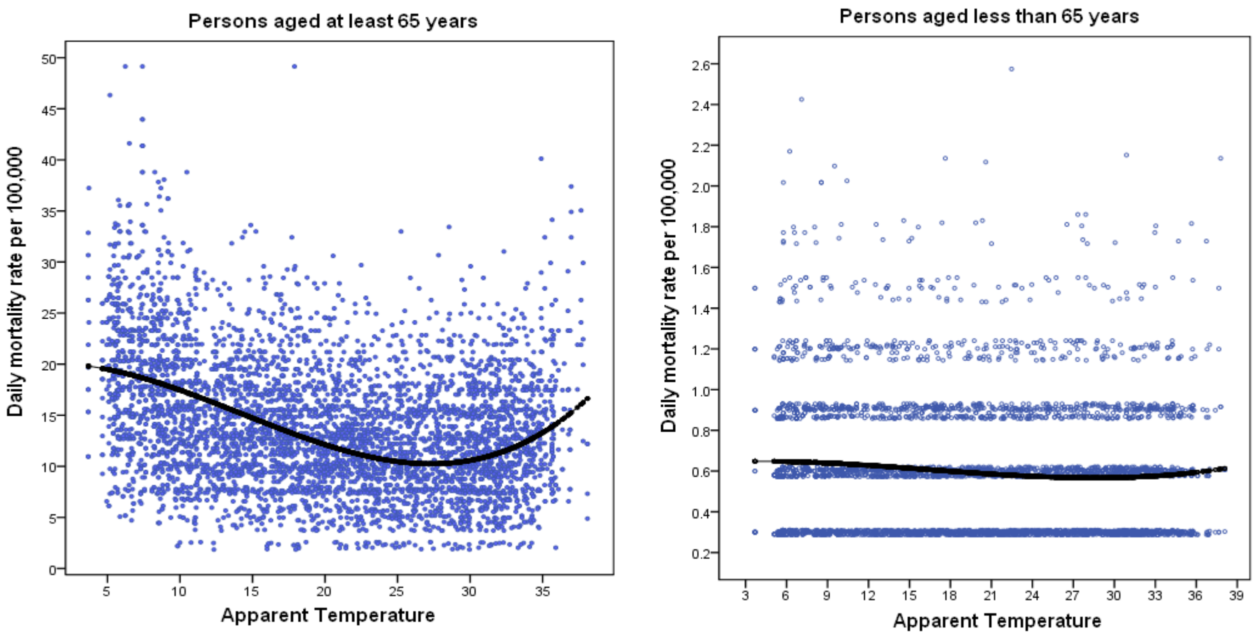

Fig. 6: Daily mortality rate/100000 for persons aged 65 years and over and for persons aged less than 65 years by apparent temperature

Seasonal differences in mortality

Mean average apparent temperature during winter during the period 1992-2005 was 11.57ºC and average daily mortality rate during this season was 18.07/100000 in persons over 65 years and 0.64/100000 in persons under 65 years. During the summer the mean average apparent temperature was 29.93ºC and the average daily mortality rate during this season was 12.46/100000 in persons over 65 years and 0.57/100000 in persons under 65 years.

Fig. 6 also shows that the rate of change in mortality is different when average apparent temperature rises above 27ºC compared to mortality below 27ºC. At temperatures above 27ºC the daily mortality rate increases more rapidly compared to when it drops below 27ºC.

For all deaths combined (above and below 65 years) the percentage increase in daily mortality rate per degree rise in temperature above 27ºC is 3.03%. The percentage increase in daily mortality rate per degree fall in temperature below 27ºC is 2.52%.

Discussion

Many studies have commented on a U-shaped relationship between daily mortality rates and apparent temperature, demonstrating an increase in mortality associated with both cold spells in winter and hot spells in summer *[6, 7]*. Several studies indicated optimal temperatures at which the number of deaths was least. Indeed these temperatures varied by location. In a study by Baccini et al, maximum apparent temperature (threshold 29.4°C Mediterranean cities and 23.3°C north-continental cities) was used to estimate the percentage increase of deaths in summer time. In that study for 1°C increase of temperature above threshold, 3.12(0.60-5.72) percentage increase of mortality was observed in Mediterranean cities and 1.84 (0.06-3.64) in north continental regions. A 3% increase in mortality per degree was found at temperatures above 27ºC in our study which is comparable to other Mediterranean countries.

Apparent temperature has been used in recent studies *[9]* combining temperature and humidity. This is important, as humidity actually pronounces the feel-like warm effect during higher temperatures and the feel-like cold effect during lower temperatures making some temperatures feel warmer during the summer months and colder during the winter months.

Although cold weather is relatively mild in Malta compared to Nordic Europe, winter months were responsible for a larger number of deaths than summer months. This follows that regions more adapted to hot weather may be less adapted to cold weather. Studies have shown that mortality increases to a greater extent for a given fall in temperature in regions such as Greece that have relatively warm winters, than in countries where priority is given to keeping warm regardless of other factors. This was associated with cooler homes and wearing of less effective clothing outdoors in countries with mild winters *[10]*. A study by the Eurowinter Group, found that the percentage increases in all-cause mortality for every degree fall in temperature below 18°C were greater in warmer regions than in colder regions (e.g. Athens 2.15% versus south Finland 0.27%). This study also found that with an outdoor temperature of 7°C, the mean living-room temperature was 19.2°C in Athens and 21.7°C in south Finland *[11]*. In our study the increase in mortality in winter occurred gradually over a larger temperature range than in the summer months. Fig 6 shows that the range between the minimum

(4ºC) and the threshold temperature (27ºC) is approximately twice the range between maximum (38ºC) and the threshold temperatures. So although the mortality rate per degree increases more gently below 27ºC rather than above the threshold temperature (2.52% versus 3.03%), the number of deaths at very low temperatures is greater than the number of mortalities at high temperatures.

Extreme temperatures affect mortality rates more severely in persons aged 65 years and over compared to younger ones. This may be due to the existence of co-morbidity as well as the ability to regulate body temperature. In elderly persons, the ability to thermo regulate body temperature is reduced, and sweating thresholds are generally elevated in comparison to younger persons *[12]*. A review of epidemiological evidence by Basu et al 2002 suggests that persons with pre-existing cardiovascular and respiratory diseases have increased risk of death associated with ambient heat exposure and that risk is higher for several population groups, including the elderly, infants and persons of low socioeconomic status *[13]*.

EuroHEAT a project coordinated by WHO/Europe and co-funded by the European Commission *[14]* produced a number of public health recommendations and actions that countries should follow in response to extreme weather/heat-waves. These include:

- The establishment of collaborative mechanisms between bodies and institutions, and a lead body to coordinate responses;
- An accurate and timely alert system;
- Heat-related health information strategies;
- Strategies to reduce individual and community exposure to heat;
- Improved urban planning, transport policies and building design to reduce energy consumption;
- Particular care for vulnerable populations;
- Provision of health care, social services and infrastructure;
- Real-time surveillance, evaluation and monitoring.

Our study has shown that the effect of climate on a population depends on a number of factors which cannot be generalized to other population groups in other regions. While in Malta attention and health warnings are given for hot weather, due to the mildness of our winters, fewer precautions are taken, and it may be pertinent to issue alerts and campaigns also during the winter months. Various health warnings released through different media are issued by the Department of Public Health when the maximum temperature reaches 30 ºC with a high humidity above 84%. In winter it is more difficult to pinpoint an exact temperature when health warnings should be given since the increase in the number of deaths is more gradual occurring over a larger temperature range. Health warnings should be given over the whole winter period (December – March). A 'campaign' to educate the public on how to keep themselves and their homes warm in winter should also be carried out on a regular basis. Maltese houses, being made of stone, offer no insulation to heat loss. They are more adapted to the hot climate and may be difficult to warm in winter. Special attention needs to be given especially to the elderly who are more likely to be hit by extreme weather conditions. More public health action plans need to be developed aimed at reducing morbidity and mortality from both cold and hot weather.

Limitations

Factors such as air pollution and seasonal influenza were not taken into account as confounders or effect modifiers in this study as this data was not available.

References

1. Huynen MM et al. (2001). The impact of heat waves and cold spells on mortality rates in the Dutch population. Environ Health Perspect, 109(5):463-70.
2. Kendrovski VT (2006). The impact of ambient temperature on mortality among the urban population in Skopje, Macedonia during the period 1996-2000. BMC Public Health, 6:44.
3. Curriero FC et al. (2002). Temperature and mortality in 11 cities of the eastern United States. Am J Epidemiol, 155:80-87.
4. Kunst et al. (1993). Outdoor air temperature and mortality in the Netherlands: a time series analysis. Am J of Epidemiol, 137: 331-341.
5. Paldy A et al. (2006). The effect of temperature and heat waves on daily mortality in Budapest, Hungary, 1970-2000. Mager Thomas, Spencer Andrew, Krabbes Frank, editors. Extreme weather events and public health responses, New York, 2006:99-107.
6. Enquselassie F et al. (1993). Seasons, temperature and coronary disease. *Int J Epidemiol*, 22: 632-636.
7. Heunis JC et al. (1995). Short-term relationships between winter temperatures and cardiac disease mortality in Cape Town. *S Afr Med J*, 85: 1016-1019.
8. Keatinge WR et al. (2000). Heat related mortality in warm and cold regions of Europe: observational study. *BMJ*, 321: 670-673.
9. Michelozzi P et al. (2007). Assessment and prevention of acute health effects of weather conditions in Europe, the PHEWE project: background, objectives, design. *Environ Health*, Apr 24; 6:12.
10. Donaldson GC et al. (1998). Cold related mortalities and protection against cold in Yakutsk, eastern Siberia: observation and interview study. *BMJ,* 317: 978-982.
11. Eurowinter Group (1997). Cold exposure and winter mortality from ischaemic heart disease, cerebrovascular disease, respiratory disease, and all causes in warm and cold regions of Europe. *Lancet*, 349:1341-1346.
12. Foster KG et al. (1976). Sweat responses in the aged. *Age Ageing*, 5:91-101.
13. Basu R et al. (2002). Relation between elevated ambient temperature and mortality: a review of the epidemiologic evidence. *Epidemiol Rev,* 24:190-202.
14. Basu R (2009). High ambient temperature and mortality: a review of epidemiological studies from 2001 to 2008. *Environ Health*, Sep 16; 8:40.