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Extreme weather and air pollution effects on cardiovascular and respiratory hospital admissions in Cyprus

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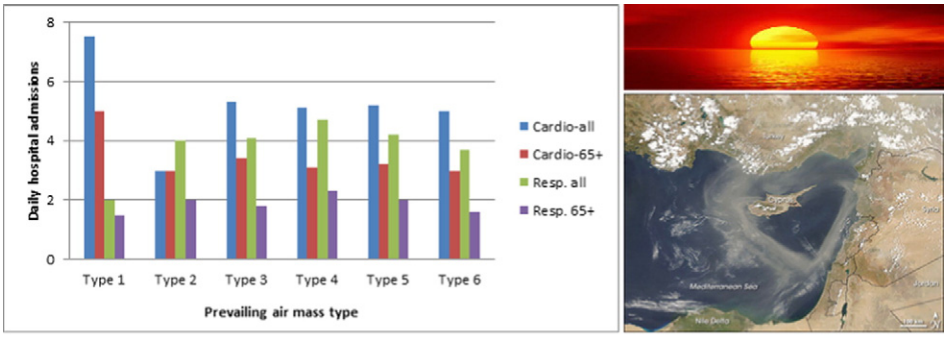
HIGHLIGHTS

- The association between extreme weather and morbidity was examined for Cyprus.
- Two air mass types were related with morbidity, in the form of hospital admissions.
- Inland vs coastal areas were also studied for cardiovascular/respiratory diseases.
- PM_{10} was associated with increased levels of cardiovascular/respiratory morbidity.
- The PM_{10} effect was more pronounced for cardiovascular morbidity.

GRAPHICAL ABSTRACT



What is the association between extreme weather/particulate matter and cardiovascular/respiratory morbidity in Cyprus?

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ABSTRACT

In many regions of the world, climatic change is associated with increased extreme temperatures, which can have severe effects on mortality and morbidity. In this study, we examine the effect of extreme weather on hospital admissions in Cyprus, for inland and coastal areas, through the use of synoptic weather classifications (air mass types). In addition, the effect of particulate air pollution (PM_{10}) on morbidity is examined. Our results show that two air mass types, namely (a) warm, rainy days with increased levels of water vapour in the atmosphere and (b) cold, cloudy days with increased levels of precipitation, were associated with increased morbidity in the form of hospital admissions. This was true both for cardiovascular and respiratory conditions, for all age

Abbreviations: $BP_{13\ h}$, barometric sea-level pressure at 13:00 LST; $BP_{8\ h}$, barometric sea-level pressure at 8:00 LST; CA, cluster analysis; $dT_{13\ h}$, dry bulb temperature at 13:00 LST; $dT_{8\ h}$, dry bulb temperature at 8:00 LST; GLM, generalized regression model; ICD, international classification of diseases; LST, local summer time; M, mean; PCA, principal component analysis; $PM_{2.5}$, particulates with aerodynamic diameter less than 2.5 μg m^{-3}; PM_{10}, particulates with aerodynamic diameter equal or less than 10 μg m^{-3}; PRE, Precipitation; $RH_{13\ h}$, relative humidity at 13:00 LST; $RH_{8\ h}$, relative humidity at 8:00 LST; SD, standard deviation; SSD, sunshine duration; $T_{d,13\ h}$, dew point temperature at 13:00 LST; $T_{d,8\ h}$, dew point temperature at 8:00 LST; T_{max}, surface maximum temperature; T_{mean}, mean temperature; T_{min}, surface minimum temperature; $T_{13\ h}$, surface temperature at 13:00 LST; $T_{8\ h}$, surface temperature at 8:00 LST; VIS, visibility; WD, wind direction; WS, wind speed; WS_{max}, maximum wind speed; $wT_{13\ h}$, wet bulb temperature at 13:00 LST; $wT_{8\ h}$, wet bulb temperature at 8:00 LST.

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groups, but particularly for the elderly, aged over 65. Particulate air pollution was also associated with increased morbidity in Cyprus, where the effect was more pronounced for cardiovascular diseases.

1. Introduction

1.1. The effect of extreme temperatures on morbidity

In recent years, an increased interest in the potential effects of climate change has led to a growth in research areas focusing on the impact of extreme weather events on human health (Haines and Patz, 2004; Johnson et al., 2005; Haines et al., 2006; Mastrangelo et al., 2006; McMichael et al., 2006; Hajat et al., 2014; Vardoulakis et al., 2014; Tsangari et al., 2015). Climate change, characterized by increases in annual mean temperature and the frequency of heat waves (i.e. prolonged periods of very hot weather) in many areas, is expected to lead to an increase in morbidity in several regions including Europe, the Middle East and North Africa (see e.g., Keatinge and Donaldson, 2004; Conti et al., 2005; Kovats and Hajat, 2008; Gosling et al., 2009).

Despite the wide variation in the type of disease or condition, there is a consistent relationship between heat waves and increased hospital admissions. Recent studies have shown that high temperatures are associated with increased hospitalizations, not only for heat-related conditions such as heat stroke, but also for more general respiratory and cardiovascular illnesses (see e.g. Ebi et al., 2004; Schwartz et al., 2004; Barnett et al., 2005; Goncalves et al., 2007; Lin et al., 2009; Michelozzi et al., 2009). Respiratory-related hospital admissions are most often affected by high temperatures, when compared with cardiovascular diseases (see e.g. Semenza et al., 1999; Kovats and Hajat, 2008; Michelozzi et al., 2009; Lin et al., 2009; Rocklöv and Forsberg, 2009; Wichmann et al., 2011; Bustinza et al., 2013).

Additionally, research points towards the association between cold spells and elevated morbidity, with strong correlations between low temperatures and increased morbidity reported for a variety of countries (see e.g. Monteiro et al., 2013), suggesting that extreme low temperatures may also affect public health.

Furthermore, extreme weather has been shown to mainly affect the more vulnerable segments of the population that include the elderly, young children, individuals with chronic diseases, impaired health and limited mobility, and lower socio-economic status (Koken et al., 2003; O'Neil and Ebi, 2009).

The effect of temperature on hospital admissions follows a U-, V- or J-shaped curve, where minimum morbidity is found at a certain temperature or within a temperature range, with an increase in morbidity below and above the threshold. A temperature threshold for specific types of diseases, as well as a geographic effect has been described for respiratory diseases (Ye et al., 2012).

1.2. The effect of particulate air pollution on hospital admissions

Several studies have examined the association between particulate air pollution and hospital admissions in the USA, Europe and Asia (see e.g. Pope, 1991; Thurston et al., 1992; Delfino et al., 1994; Schwartz, 1994, 1995, 1996; Schwartz and Morris, 1995; Anderson et al., 1998; Spix et al., 1998; Wong et al., 1999; Koken et al., 2003; Dominici et al., 2006; Goncalves et al., 2007; Colais et al., 2012). These studies show that exposure to airborne particle matter (PM_{10} and $PM_{2.5}$) increases the risk of hospital admission for cardiovascular and respiratory diseases.

1.3. Air mass types

While most studies on the effect of extreme weather on human health consider that air temperature is the most important risk factor to human health, the main climatic parameters, such as daily absolute maximum and minimum temperatures, cover only a fraction of the total input of climate and weather on biological systems and organisms. A significant role can also be played by other meteorological parameters such as wind speed, dew point, humidity and barometric pressure. Thus, synoptic weather indices have been introduced, in place of single meteorological variables, to examine their impact on respiratory and cardiovascular illness, within specific geographical areas (e.g., Kalkstein, 1991; Pope and Kalkstein, 1996; Samet et al., 1998; McGregor, 1999; Kassomenos et al., 2001; Garcia et al., 2002, 2005; Kassomenos et al., 2007, 2010). Synoptic weather indices describe air mass types which contain all the appropriate meteorological information to characterize a day in terms of meteorology. Since air mass types can be predicted two or three days in advance, they can be a very useful tool for forecasting, providing valuable information to public health authorities.

1.4. Description of the study area

Cyprus is situated in the eastern part of the Mediterranean Sea and covers an area of 9251 km^2. It has a typical Mediterranean climate characterized by warm dry summers (from June to September) and wet changeable winters (from November to March), separated by short autumn (October) and spring (April and May) seasons with rapid transitions. The average maximum temperature in the warmer months (July and August) is around 36 degrees Celsius (°C).

Predominantly clear skies and high sunshine amounts result in large seasonal and daily temperature differences between the sea and the interior of the island, driving considerable local phenomena (sea breezes) near the coast. The central Troodos mountain, rising to 1951 m and, to a lesser extent, the long narrow Kyrenia mountain range with peaks of about 1000 m also play an important part in the meteorology of Cyprus (Price et al., 1999).

Specifically, during summertime, the island is mainly under the influence of a shallow trough of low pressure extending from the great continental depression centered over Southwest Asia. This results in high temperatures with almost cloudless skies. Rainfall is almost negligible during this time of the year. However, isolated thunderstorms may sometimes occur, contributing to less than 5% of the total annual rainfall (Price et al., 1999). It has been well documented that the depressions affecting the area of Cyprus are associated with various types of weather. Climatological studies (see, e.g. Michaelides et al., 2004; Nicolaides et al., 2004, 2006) have shown that showery weather is associated mainly with depressions coming from the west, i.e. the main body of the Mediterranean Sea, whereas cold and mainly dry weather is predominant with depressions coming from the north. Weather connected with dust events is largely associated with depressions affecting the area from the east and south, commonly referred to as Saharan events, which are characterized by extreme concentrations of dust in the atmosphere, resulting in low visibility and poor air quality (see, e.g. Retalis and Michaelides, 2009; Paschalidou et al., 2011).