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A Retrospective Study on Heat-Related Mortality in an Elderly Population During the 2003 Heat Wave in Modena, Italy: The Argento Project

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Background. Summer 2003 witnessed an excess in heat-related mortality in the elderly population. The Argento Project was planned to define risk factors for heat-related death in Modena, Italy, during the hottest month of 2003 (August).

Methods. We performed a retrospective, case–control study of a cohort of 394 older persons living in Modena, 197 dead (cases) and 197 survivors (controls). A questionnaire to collect information about demographic, social, environmental, and clinical characteristics and about causes of death was completed.

Results. Cases were more likely to be living in a nursing home and needing assistance ($p = .024$, and $p < .001$, respectively). Survivors were living on higher level floors ($p = .046$). Spending the summer in Modena was significantly related to poor outcomes ($p < .01$). A higher number of cases were using public health services ($p < .001$). Individuals who died had a greater degree of comorbidity and dependence ($p < .001$); they were cognitively impaired ($p < .001$), took a larger number of drugs ($p < .001$), and had a greater number of hospital admissions ($p < .001$). Multivariate analysis showed that patients who spent the summer in Modena had a higher mortality. Other predictors of death were the use of home public-integrated assistance, a higher comorbidity and a higher degree of disability; the loss of at least 1 Activity of Daily Living (ADL) represents the strongest risk factor of heat-related death.

Conclusions. Our study identifies the major risk factors of heat-related death in the elderly population. With the creation of an up-to-date database, when a new heat wave will come, it will be possible to identify frail persons for preventive targeted strategies.

IN the summer of 2003, Europe recorded an excess in mortality, increasing dramatically with age. In France, the European country most involved, the proportion of excess deaths rose from 20% among the 45–54 year age group to 70% among the 75–94 year group and 120% among the >94 year age group (1,2). The Italian Ministry of Health estimated an initial impact of 4175 deaths in excess among people older than 65 years between July 15 and August 15, compared to the previous year. In Rome, the excess mortality rose from 2.5 among the 65–74 year age group to 40.2% among the >85 year age group (3); the Italian Bureau of Statistics (ISTAT) (4), however, reported an excess of 19,780 deaths countrywide during June–September 2003, as compared to 2002.

A heat wave is an isolated episode of hot weather lasting ≥3 consecutive days with air temperature above 32°C (5). Heat waves have a much greater health effect in cities than in surrounding suburban and rural areas; first, air temperatures have higher values in densely built areas, a phenomenon widely known as an ''urban heat island''; second, air pollution is usually higher in urban areas and, in some studies, has demonstrated a synergistic effect with heat on mortality (5).

It is well known that adverse climatic conditions have a negative effect on global health, leading to a higher mortality, particularly in large urban areas and most of all in the frail subgroups of the population (children and elderly and ill people). This effect becomes clear after a few days after exposure (6); the older population is at significant risk for hyperthermia and hypothermia; concomitant diseases, multiple medications, and altered perceptions increase the risk of developing complications during heat waves (7).

The available studies on heat-related death are designed to evaluate the excess of mortality in nonselected populations, often without using a control group (8). Owing to increased climatic variability, it is likely that in the future analogous periods will recur, in particular in continental areas near the sea. This likelihood underpins our study (the Argento Project) to define risk factors for heat-related death in a specifically geriatric population in Modena during August 2003 (the hottest month of the year), a study controlling for the usual effects of meteorologic and air pollution variables. The results of our analysis could help in refining targeted heat-wave-response activities in Italy to prevent future heat-related deaths among high-risk populations.

Table 1. Study Questionnaire

Demographic	Sex, date of birth, place of birth, marital status, place of residence, rural/urban residential area, education
Housing	Floor, presence of elevator
Social	Where did they live (at home, in nursing home)? With whom did they live (alone, with relatives, with private assistance)? Did they use social assistance?
Clinical	Disability (Activities and Instrumental Activities of Daily Living, ADL/IADL) (9,10), comorbidity (Cumulative Illness Rating Scale, CIRS) (11), principal diseases, drugs, number of falls, number and type of hospital admissions, number and type of specialist visits, presence of cognitive problems
ISTAT (only for case group)	Date and place of death, causes of death
Meteorological	Temperature and percent humidity expressed as maximum, medium, and minimum values, Thom index, PM_{10}, NO_2, ozone

Note: ISTAT = Istituto Nazionale di Statistica (National Bureau for Health Statistics); PM_{10} = air pollutant consisting of small particles with an aerodynamic diameter ≤10 microns; NO_2 = nitric oxide.

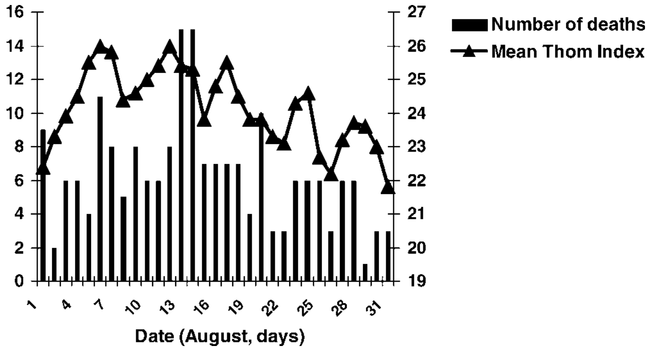

Figure 1. Daily mortality and Thom index in Modena, August 2003. *Filled bars:* number of deaths; *filled triangles:* mean Thom index.

Methods

The Argento Project is a retrospective, case–control study, approved by the Local Ethical Committee. Observed deaths between August 1 and 31, 2003 in Modena City of persons older than 70 years were obtained from the Communal Census Database. From the same database a control group of survivors (matched for age and sex and living in the same area during the same period) was randomly selected. We verified data of dead persons using the Database of the Epidemiology and Statistical Service of the local health authority (''Azienda Unità Sanitaria Locale''; AUSL).

A total of 394 persons living in Modena were recruited, 197 deaths (case group) and 197 survivors (control group). All the participants and when not available, relatives, gave informed consent for collection and the use of data.

For each person a questionnaire to collect information about demographic, social, environmental, and clinical characteristics was completed (Table 1). Mortality data were obtained from the National Bureau for Health Statistics (ISTAT) (4). The diagnoses were coded using the *International Classification of Diseases, 9th Revision* (ICD-9) (12). For both cases and controls, clinical, demographic, social, and environmental data were collected by phone, with an interview to family physicians; in case of missing data, we also phoned the relatives to obtain more precise information to complete the questionnaire and more insights on the circumstances of death. To confirm the information received and in case of missing data, we used the AUSL database.

Meteorological information related to the period between August 1 and 31, 2003 was given by the Regional Meteorological Service of the Agenzia Regionale per la Prevenzione e l'Ambiente (ARPA). The analysis took account of the maximum, medium, and minimum daily values of temperature, relative humidity, and the Thom index (13). Thom index, also known as Discomfort Index, is useful to evaluate how current temperature and relative humidity can affect the sultriness or discomfort sensation. It can be expressed by the following formula:

$$0.4 \times (T_a + T_w) + 4.8,$$

where T_a is the ''dry bulb'' temperature, and T_w is the ''wet bulb'' temperature.

When the index is 24, discomfort appears, increasing progressively; at 28 or more, a physical and cognitive deterioration of general conditions starts. The heat shock threshold is 32 (13). We did not analyze the rate of rainfall, as no abnormal data with respect to other periods of 2003 or previous years were observed in the city of Modena. Data on air pollution were collected by five pollution stations located in five different zones of the town. For each participant, values of different pollutants (medium and maximum nitric oxide, particulate matter <10 nanometers (PM_{10}), and ozone, monthly and daily values) were recorded from the nearest station to his or her house.

Statistical Analysis

Data were analyzed with SPSS (11th version; SPSS, Chicago, IL). The chi-square test was used to compare proportions in univariate analyses of dichotomous variables and to calculate the odds ratios (OR) and the 95% confidence intervals (CI). The γ test was used to study ordinal variables. The variables significantly associated with the outcome of interest in univariate analyses were entered into a multivariate logistic regression model (backward stepwise) to assess their independent association with the outcome (mortality).

Results

In August, the mean values of temperature, relative humidity, and Thom index were 27.32°C, 57.57%, and 24.17°C, respectively, while the mean values of PM_{10}, ozone, and nitric oxide were 33.68 μg/m^3, 142.10 μg/m^3, and 30.06 μg/m^3, respectively. Thom index was above the threshold of 24 throughout the month; the highest number of deaths occurred around August 15 (Figure 1). Air pollution—expressed as daily levels of PM_{10}, ozone, and nitric oxide—was not related to higher mortality.

There were no differences between the two groups in terms of marital status, education, residential area, or presence of an elevator inside in the house (Table 2). Survivors

Table 2. Demographic and Social Characteristics of the Studied Sample

Characteristics	Cases (*N* = 197)	Controls (*N* = 197)	*p**
Demographic			
Age, y	83.0 ± 7.2	82.9 ± 6.7	.113
Males, %	44.0	41.8	.493
Married, %	47.0	44.0	.938
Living in rural areas, %	32.5	40.4	.452
Education, primary (%)	55.4	57.3	.925
Presence of elevator, %	30.0	35.0	.171
Social			
Living . . .			
In nursing home	18.1	7.8	.024
Alone	16.8	24.2	.487
With husband or wife	30.6	36.6	.546
With other relatives	27.5	33.5	.818
With private personnel	6.6	1.5	<.01
With nursing home staff	18.4	4.1	<.01
Passing summer in Modena	85.1	64.8	<.01

Note: Data are expressed as percentages; age is expressed as mean ± standard deviation.

lived on floors at a higher level than those on which people who died lived (OR = 0.61, 95% CI, 0.38–0.98; $p = .046$).

The highest number of cases lived in nursing homes (Table 2). The survivors were more likely to be living alone, although this result is not statistically significant; the number of persons needing assistance (nursing home staff, private assistance) was higher in the case group (Table 2).

Spending the summer in Modena (rather than at holiday resorts) was significantly related to poor outcomes (OR = 4.24, 95% CI, 2.36–7.62; $p < .01$). There were no differences between the two groups as far as use of social services was concerned, but a significantly higher number of cases used public health services (home public assistance) (OR = 3.77, 95% CI, 2.22–6.39; $p < .01$).

Individuals who died had a complex clinical profile: They were more likely to have cognitive problems and a high degree of comorbidity and dependence. Moreover, they took

Table 3. Clinical Features of the Studied Sample

Clinical Features	Cases (*N* = 197)	Controls (*N* = 197)	OR	95% CI	*p**
Specialist visits in the last year	59.1	64.8	0.78	0.51–1.20	.281
Falls	15.3	13.3	1.174	0.64–2.17	.643
Cognitive impairment	52.4	24.6	3.38	2.16–5.28	<.001
High CIRS score	56.0	44.0	2.14	1.25–3.67	<.001
More than 4 drugs	53.9	38.7	1.85	1.23–2.78	<.001
Loss of at least 1 ADL	50.9	17.1	5.03	3.03–8.35	<.001
Home public assistance	33.5	11.8	3.77	2.22–6.39	<.001
Hospital admission in the previous year	65.8	23.0	6.46	4.14–10.81	<.001

Notes: Data are expressed in percentages.

*$p < .05$ is considered statistically significant.

OR = odds ratio; CI = confidence interval; CIRS = Cumulative Illness Rating Scale; ADL = Activities of Daily Living; falls = ≥1 fall in the last year; cognitive impairment = presence of cognitive problems as referred from relatives/general practitioners/nursing home staff.

Table 4. Principal Causes of Death

ICD-9 CM Codes	Number	Percentage
402.9	23	11.7
410.0	6	3.0
414.8	2	1.0
414.9	2	1.0
415.1	2	1.0
428.9	4	2.0
429.0	1	0.5
429.2	1	0.5
429.9	4	2.0
290.0	12	6.1
290.8	8	4.1
436	10	5.1
438	10	5.1

Notes: Codes 402.9, 410.0, 414.8, 414.9, 415.1, 428.9, 429.0, 429.2, and 429.9 are cardiac diseases (hypertensive cardiac disease, acute myocardial infarction, coronary heart disease, pulmonary embolism and infarction, heart failure, other cardiac diseases); codes 290.0 and 290.8 are dementia and psychotic conditions; codes 436 and 438 are acute cerebrovascular diseases and their consequences.

ICD-9 CM = *International Classification of Diseases, 9th Revision, Clinical Modication.*

a higher number of drugs and had a greater number of hospital admissions and specialist visits in the year before death (Table 3). The results described in Tables 2 and 3 did not change after excluding persons who spent the summer at holiday resorts.

No death was considered directly related to heat shock; both acute and chronic cardiovascular and cerebrovascular diseases were the more frequent causes of death (22.7%, Table 4). The majority of patients died in hospital (53.8%), whereas 27.7% died at home, and 18.5% in the nursing home.

Multivariate Analysis

Variables that were statistically relevant during the univariate analysis were used to build a multivariate model to evaluate risk factors for heat-related mortality, after correcting for mean and maximum levels of PM_{10}, ozone, and nitric oxide. The results are shown in Table 5.

Independently of other factors, elderly patients spending the summer in Modena had a higher mortality. Other variables independently related to death were the presence of home public integrated care, and a higher comorbidity and disability; in particular, the loss of at least 1 Activity of Daily Living (ADL) represents the strongest risk factor of heat-related death.

In the multivariate model, living on a floor at higher level, in a nursing home or with private personnel, the presence of cognitive decline, the use of more than four drugs, and the

Table 5. Multivariate Analysis

Variables	OR	95% CI	*p*
Passing summer in Modena	3.03	1.53–5.90	<.001
Home public assistance	3.27	1.64–6.52	<.001
High comorbidity (CIRS score)	1.25	1.10–1.62	<.001
Loss of ≥1 ADL	3.56	2.02–6.25	<.001

Note: OR = odds ratio; CI = confidence interval; CIRS = Cumulative Illness Rating Scale; ADL = Activity of Daily Living.

number of hospital admissions in the previous years were not associated with higher mortality.

The results shown in Table 5 did not change after running the analysis excluding persons who spent the summer on holiday resorts.

Discussion

During June–August 2003, Italy was one of the countries most affected by the heat wave, with an increase in mortality of 19.1% between July 16 and August 31 in the population older than 65 years. The greatest excess in mortality was observed in northwest Italy (Milan, +23%); the old (75–84 years) and the very old (>85 years) were the age groups most affected (3).

In Modena, the hottest month of the 2003 summer was August; globally, the effects seem to have been very quick after the temperature increased, the excess of deaths coinciding with peaks of temperature or with a lag of 1 day and going down with a lag of a few days after a long period of very high temperatures (Figure 1); this phenomenon is in line with at least another study (3).

The problem of heat-related deaths was addressed several years ago, after the great heat wave in Chicago in 1995; researchers found a close relationship between the risk of summer deaths and poor clinical conditions, disability, loneliness, and the lack of air-conditioning facilities (14); individuals experienced multiorgan dysfunction with neurologic impairment, moderate to severe renal insufficiency, disseminated intravascular coagulation, and acute respiratory distress syndrome (15). Zhao and colleagues (16) showed that people who lived in poor social conditions have a significantly higher risk of summer death.

In the literature, the profile of the patient at risk of heat-related death is well known: Advanced age, preexisting diseases, loneliness, indigence, living conditions such as a small apartment on a high floor and no air conditioning are important risk factors. Nevertheless, when the effects of chronic debilitating diseases in the elderly population are minimized, their heat tolerance and thermoregulatory responses are comparable with those of younger individuals (17).

Our data recognized the clinical pattern of an increase in the number of deaths of elderly people during the hot summer: high comorbidity, disability, spending the summer in Modena, and home public assistance. Older people are at increased risk from heat death for a number of reasons: The ability to compensate for extreme heat and humidity becomes less efficient with aging, the presence of several chronic diseases is more likely (and their impact is exacerbated by heat); and some medications to treat chronic diseases make people more prone to health hazards from hot weather. In our study, survivors were living on higher floors: This finding is in contrast with the literature, because lower level floors are cooler. Nevertheless, survivors who lived on higher floors were more likely to be independent, as many houses lacked elevators. The same concept can be expressed as far as living alone is concerned: Elderly persons who live alone are more likely to be independent and in healthier living conditions.

Our study confirms the importance of high comorbidity and disability as factors significantly associated with a high risk of death; nevertheless, multivariate analysis shows, unexpectedly, that home public assistance is significantly related to higher mortality. We do not think that our data on this topic suggest underlying frailty not captured by other measures, or different socioeconomic status. In our opinion, this result challenges the quality and appropriateness of health interventions aimed at older and frail people living at home in big towns. In our study, living in a nursing home was associated with higher mortality only in univariate analysis. More precisely, living in a nursing home does not cause a higher mortality; rather, it is caused by the higher comorbidity and frailty of patients living in this setting. Another possible explanation of the higher mortality in persons who were assisted by home public assistance is the more frequent presence of air conditioning in nursing homes than in private houses; air conditioning has been recognized as a powerful protective factor to prevent heat-related mortality (18). Because of missing data, we did not analyze the effect of air conditioning on reducing mortality.

Epidemiological studies show that health impacts of the heat wave range far beyond hyperthermia. Global, cardiovascular, and respiratory mortality are the indicators most often mentioned to show a significant relationship with high temperatures; heat-related deaths (dehydration, hyperthermia, heat stroke) are rarely diagnosed clinically as being due to heat and are recorded as such (19,20). In our study, heat shock or other heat-related diseases are not identified as the principal causes of death; in contrast, typical age-related chronic diseases such as cardiovascular and neurologic pathologies have a great impact in causing heat-related deaths. The excess of cardiovascular diseases as a cause of mortality occurred mostly in hospital; cardiovascular diseases seem to be a good indicator of risk of death for elderly patients. Epidemiological studies show that health impacts of the heat wave range much further than hyperthermia alone.

Many studies suggest a synergic effect between ozone and/or particulate pollution and heat on deaths and a high contribution by such pollution to the final toll (21,22). Nevertheless, the relationship between mortality in summer during heat waves seems to be closer than that between mortality and other environmental factors, such as atmospheric pollution (23). In our study we failed to find correlations between mortality and concentrations of PM_{10}, ozone, and nitric oxide. This is in line with other studies; in France air pollution, longer term temporal trends, and seasonal fluctuations did not appear as the main factors affecting mortality during the heat wave (19).

In the presence of a functioning Heat Health Watch Warning System the prevention plan can reach those people most at risk of heat-related death. Heat-related diseases are preventable with adequate warning and a fast and well-organized response to the emergency. Any successful intervention requires identification of elderly persons at high risk (6). Preventive intervention should focus on factors recognized to be important in heat tolerance: aerobic fitness, body fat, and body weight, for instance, are fundamental to maintain heat tolerance with aging (17).

Unlike many North American cities, European cities are not well-prepared to deal with the problem of heat waves; most of the programs do not include any intervention apart from issuing a passive warning to the general public or to the local public health agencies (24). In Philadelphia, the preventive program includes activation of a heatline, involvement of neighbors or relatives, home visits by field teams of the Department of Health, increased medical emergency staffing, and facilitation of access by elderly persons to air-conditioned service facilities (25).

With the creation of an up-to-date database including data about elderly people, it will be possible to identify frail persons and implement preventive targeted strategies that involve different professional figures (e.g., physicians, nurses, therapists, social assistants, volunteer associations). The evidence and anticipation of adverse health effects will indicate priorities for planned adaptive strategies and, crucially, will strengthen the case for preventive policies (26). Alert and response systems based on monitoring of climate-related risks, emergency room activity, and mortality should be implemented, and the response capacity of the social and health services improved; the above-mentioned database could make the health care system more effective in exceptional climatic conditions.

The major limit of this study is the retrospective design; prospective studies are needed to more precisely identify risk factors of heat-related death and to test the usefulness of preventive programs. Moreover, data were collected only during summer, so we did not have the opportunity to compare our results with other possible outcomes obtained in other periods of the year. Future research that compares risk factors for mortality and causes of death during hot months with those during cooler months could help to clarify this limitation.

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