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Research report

Global warming possibly linked to an enhanced risk of suicide: Data from Italy, 1974–2003

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Abstract

Background: The global increase in surface temperature (known as global warming) was found to impact on mortality through ill health, particularly among the elderly and in summer. This study sets out to explore the impact of global warming on suicide mortality, using data from Italy.
Methods: Monthly data on suicide mortality and temperature were obtained for a 30-year period (from January 1974 to December 2003), and the relation between them was investigated using the Gaussian low-pass filter, linear correlation analysis and rank analysis.
Results: For males, increasing anomalies in monthly average temperatures associated to a higher monthly suicide mean from May to August and, to a lower extent, in November and December. In January, on the other hand, increasing anomalies in monthly average temperatures appeared to be coupled to a lower number of suicides. For females, the links between temperature and suicides are less consistent than for males, and sometimes have a reverse sign, too.
Limitations: Data could not be analyzed according to age, since this information was not available across the whole time interval. The use of monthly data, instead of daily data (unavailable), is another major limitation of this study.
Conclusions: An improvement in the ability of communities to adjust to temperature changes by implementing public health interventions may play an important part in preserving the wellness of the general population, and also in limiting the worst consequences of suicidal behaviour.
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Keywords: Suicide; Global warming; Risk factors; Sex/gender; Public health

1. Introduction

Hot temperatures are associated with increased mortality (MacFarlane, 1978; Hajat et al., 2002; McMichael et al., 2006). Predominantly, hot weather affects people with limited adaptive responses, with susceptible population including the elderly, those with chronic diseases and socially deprived groups (Hajat et al., 2002; Basu and Samet, 2002; Schwartz, 2005; Michelozzi et al., 2006); the same people suffer an enhanced risk of suicide, too (World Health Organization, 1999; Levi et al., 2003). Indeed, hot temperatures associate to an increased risk of suicide mortality in both

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sexes (Preti, 1997; Deisenhammer, 2003; Lee et al., 2006). In recent years, repeated episodes of heatwaves were entwined with a progressive rise in average surface temperature all over the world (Meehl et al., 2000; Brunetti et al., 2006). This progressive increase in surface temperature should associate to a proportionally higher risk of suicide, particularly in the hotter months of the year.

Despite some reports describing a reduction in suicide seasonality (Yip et al., 2000; Ajdacic-Gross et al., 2005), as a likely reflection of an improvement in mental disorder recognition and treatment over time (Rihmer, 2001), most studies found no changes or even an increase in the seasonal amplitude of suicides (Rock et al., 2003; Nakaji et al., 2004; Bridges et al., 2005) that would imply some effect of global warming on the risk of suicide. In Italy, the variance accounted for by seasonal harmonics in the monthly distribution of suicides decreased from 1974 to 1994, then began to increase progressively and more evidently in 1999–2003 (Rocchi et al., in press), in coincidence with the repeated summer heatwaves recorded in Italy (Schär et al., 2004; Brunetti et al., 2006). However, so far no study had tested explicitly the hypothesis that the recently observed rise in surface temperature is linked to an increase in the risk of suicide over time. This study set out to explore the impact of the recent climate change brought about by global warming on suicide mortality, using data from Italy.

2. Method

Data on suicide were taken from the records of the Istituto Nazionale Italiano di Analisi Statistiche (ISTAT), and relate to the years 1974 to 2003. They were collected from Police and Carabinieri (Military Police), who compile detailed case reports based on the preliminary death certificate completed by the examining doctor, and on extensive questioning of key informants and relevant witnesses. Classification of suicides was made according to the eighth (VIII) and ninth (IX) revisions of the ICD (International Classification of the Diseases). Data report sex and time distribution of suicide deaths; analyses refer to these different groups of data.

Changes in rates over time were analyzed using a test for trend. Linear regression analysis of suicide rates by gender over 30 consecutive years was performed. A 2-tailed *t*-test was performed to test the hypothesis of a significant slope. As an alternative to the simple linear regression model a quadratic model was examined, whereby a second explanatory variable is added, which is simply the square of the year. This model assumes the possibility of a yearly change in rate and assumes that suicide rates follow a single smooth parabolic trend instead of strictly linear trends; this model can explain changes whereby a rise is followed by a decrease in suicide rates (or the reverse).

Data on temperature were drawn from Brunetti et al. (2006) and from cooperation with the University of Milan. They refer to monthly anomalies in Italian average temperatures with respect to the climatological mean, 1961–1990 (IPCC, 2001). Anomalies represent the time-depending factor of temperature, whereas the climatological mean in 1961–1990 represents the normal values of temperature that are characteristic to a geographic area (the whole of Italy, in our study). In fact, the 1974–2003 temperature values presented in our paper are algebraic additive anomalies with respect to the 1961–1990 average values (i.e., the 1961–1990 values have been subtracted from the 1974–2003 ones). The Intergovernmental Panel on Climate Change (IPCC) of the World Meteorological Organization (WMO) fixed the reference period for all meteorological variables in the time interval 1961–1990, considered as representative of the climatological "normal" over the planet (IPCC, 2004a). The use of anomalies with respect to the 1961–1990 average values guarantees to avoid both redundant geographical information (i.e., for example, it is obvious that we expect higher temperatures at lower latitudes) and, when referring to temperatures still, anomalously deviant periods (as, for example, the abnormally cold 1940s in Europe) that may cause a bias in the evaluation of possible thermometric trends. We were not interested in the typical geographic average values of temperature, but rather in the variability and change that are encompassed by the concept of temperature anomaly, in order to investigate a possible relationship (and/or cause–effect link) between temperature variability and suicide occurrence in Italy. In fact, heat-related mortality is dominated by the difference between temperature and average climate, rather than by gradual increases in extreme temperatures (Patz et al., 2005). As a matter of fact, the mean surface temperature in Italy has been increasing over the last two centuries, with a rate of +1 °C per century (Brunetti et al., 2006), a rate similar to the rest of Mediterranean Europe; in particular, most of the increase was observed, by means of progressive trend analysis, from the late 1970s peaking in 2003, the warmest year of the last two centuries in Italy (Fig. 1).

The possible link between temperature and suicide occurrence has been analyzed by means of a Gaussian low-pass filtering procedure (Adelmann, 1997). This method removes the low-frequency effect of trivial time

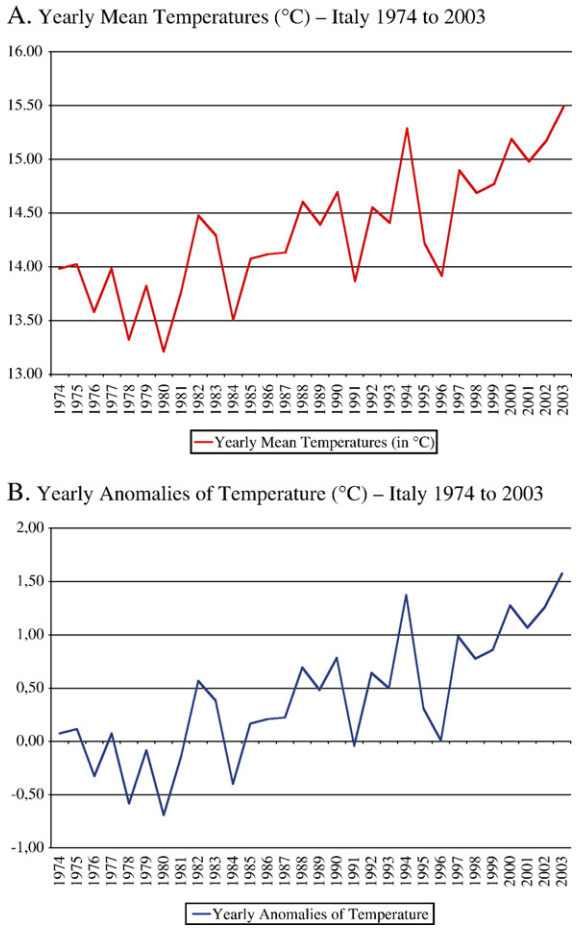

Fig. 1. Trends in yearly mean temperatures (A), and in anomalies of temperature (B) in Italy (1974–2003). On axis *Y*, temperatures in °C, on axis *X* the years.

trends, allowing to determine meaningful correlations between two variables (more properly, between the high frequency residuals of two variables, such as temperature and suicide occurrence) without the misleading effects due to uneven trend over time, and to the trivial low-frequency impact of both increasing population and temperature growth in Italy. These, in fact, would lead to a non-significant coupling of the two variables chosen for our study. Gaussian low-pass filtering, therefore, makes it possible to compare the residuals of both temperature and suicide occurrences, allowing a direct investigation of the contribution of the first to the latter. Linear correlation coefficients have been calculated between temperature and suicides by season and month. According to the standard climiatological definition of seasons (IPCC, 2004b), seasons were defined as follows: spring (March, April, May); summer (June, July, August); autumn/fall (September, October, November); winter (December, January, February). To take into account and to detect the effect of deviant values, rank order coefficients were calculated as well. Effect size was measured according to Cohen (1988). The suggested intervals for correlation coefficients are: *r* around 0.10 = small effect, *r* around 0.24 = medium effect, and *r* around 0.37 = large effect.

3. Results

3.1. Time trend of suicide rates

A total of 71 227 male suicides and 26 466 female suicides were identified in Italy over the 30-year study period, with a yearly mean of 2374 male suicides (average yearly rate = 8.54 per 100 000, SD = 1.63, range 5.84 to 11.20) and of 882 female suicides (average yearly rate = 3.00 per 100 000, SD = 0.09, range: 2.31 to 4.00) throughout the study period. Both male and female suicide trends showed a rising trend, with an evident

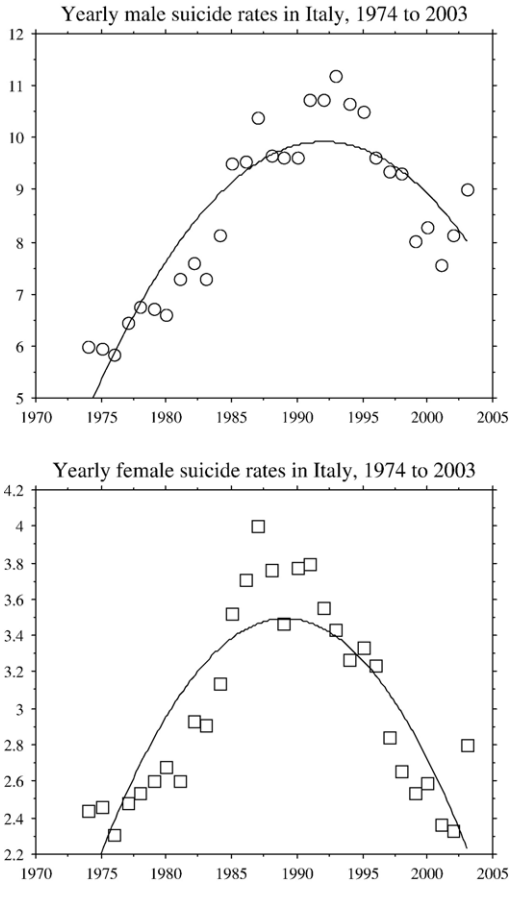

Fig. 2. Trends in the yearly distribution of suicide rates in Italy (1974–2003), by sex. On axis *Y* suicide rates per 100 000, on axis *X* the years.

peak in the 1987–1994 period and a decrease thereafter (Fig. 2). A quadratic model (regression of years on the absolute number of suicides per year) fits significantly better than the simple linear regression model: for males, Adjusted $R^2=0.78$, $P=0.0001$, ($F=53.12$, $df=2/27$) in the quadratic model, as against Adjusted $R^2=0.34$, $P=0.0004$ in the simple linear regression model; for females, Adjusted $R^2=0.71$, $P=0.0001$ ($F=36.47$, $df=2/27$) in the quadratic model, as against Adjusted $R^2=0.01$, $P=0.48$ in the simple linear regression model. In the very last years, however, suicide rates increased in both sexes again (Fig. 2).

3.2. Thermometric influence

With males, increasing anomalies in monthly average temperatures were associated to a higher monthly suicide mean from May to August, and in November and December to a lower extent (Table 1). In January, on the other hand, increasing anomalies in monthly average temperatures appeared to be coupled to a lower number of suicides. With females, the links between temperature and suicides were less consistent than with males, and sometimes they have a reverse sign (negative rather than positive) (Table 1).

Using rank ordering, we were able to identify deviant points (or statistical outliers) in our series: by excluding deviant points (no more than 1–2 per series), a sensitive increment in the association between our measure of temperature and suicide was observed (Table 1). The exclusion of deviant points is reasonable if we consider that we do not expect temperature anomalies and suicide residuals to be coupled fully, unlike a univocal cause–effect relationship: it is self-evident that a human variable as suicide occurrence is linked to several causes that include also a simple stochastic occurrence, which may deviate from the general trend due to an underlying main variable. The detection of a deviant point is therefore a useful exercise to take these possible stochastic non-causal occurrences into account in a critical way. The exclusion of deviant points made even more evident that the links between anomalies of temperature and suicides concern the warmest months from May to August, and also some of the coldest months, November to February, January being an exception. Even after the exclusion of deviant points, female

Table 1
Relationship of temperature with suicide occurrence in Italy, by sex — correlation coefficients

	r ($n=90$)	P		r ($n=30$)	P	Excluded points	r ($n=30-$e.p.)	P
Males								
Spring	0.03	–	March	−0.14	–	–	−0.14	–
			April	0.07	–	–	0.07	–
			May	0.27	0.075	1986, 1995	0.45	0.007
Summer	0.28	0.004	June	0.27	0.075	1982, 1987	0.49	0.004
			July	0.28	0.067	1982, 1992	0.39	0.020
			August	0.30	0.054	1994, 2001	0.55	0.002
Autumn/fall	0.15	0.094	September	0.17	0.185	1980, 1996	0.30	0.060
			October	0.04	–	–	0.04	–
			November	0.24	0.100	1992, 1993	0.45	0.007
Winter	−0.01	–	December	0.24	0.100	1985, 1991	0.38	0.023
			January	−0.24	0.100	–	−0.24	0.109
			February	0.18	0.171	1987, 2003	0.43	0.011
Females								
Spring	−0.02	–	March	0.10	–	–	0.10	–
			April	−0.23	0.111	–	−0.23	0.111
			May	0.00	–	1978, 1987	0.23	0.112
Summer	0.05	–	June	−0.06	–	–	−0.06	–
			July	0.31	0.048	1984	0.43	0.010
			August	−0.01	–	1986, 1996	0.30	0.060
Autumn/fall	0.00	–	September	−0.16	–	–	−0.16	–
			October	0.03	–	–	0.03	–
			November	0.20	0.145	1984, 1992	0.33	0.043
Winter	−0.01	–	December	0.14	–	1979, 1987	0.24	0.109
			January	−0.02	–	–	−0.02	–
			February	0.18	0.171	1996	0.27	0.079

suicides seem less affected by the increase in anomalies of temperature over time.

4. Discussion

We found important links between anomalies in monthly average temperatures and the number of monthly suicides registered in Italy over the last 30 years (1974 to 2003). These links seem solid enough among males, but not so among females. Among males, and in late spring till the end of summer, higher residuals in monthly temperature anomalies are mirrored by a higher number of suicides. To a lower extent, the same feature can be found in November and December, whereas in January the relationship has a negative sign (anti-correlation). Spring and summer have recorded the most consistent trend towards higher temperature values over the last 100 years in Italy (Meehl et al., 2000; Brunetti et al., 2006). It is interesting that the last years of our time series saw a reversal of the trend towards decreasing suicide rates that had been observed in the preceding decade, in both males and females.

At a first glance, more suicides in the months with a greater thermometric discomfort can be attributed, at least partially, to the effect of global warming on survival after attempt. Very simply, extreme temperature might increase the negative impact of body self-harm on the chance of surviving after a suicide attempt (Rocchi et al., 2004). For unknown reasons, males seem more sensitive to this effect than females: heterogeneity of the impact of temperature on mortality for recent heat stress was reported in Italy across different causes of death (Michelozzi et al., 2006). It may be that changes in the ability of individuals to adjust to high temperatures explain, in part, the differences we found between males and females.

Heat stress, however, cannot account for all the correlations we found. In both males and females, during the coolest months, with the notable exception of January, higher residuals in temperature monthly series associate to a higher number of suicides per month. This is particularly evident with both sexes in November, a month when warmer temperature anomalies are normally coupled with an increased cloud cover and with fewer hours of direct sunshine, a climatological feature that may, at least in part, explain the further discomfort imposed on susceptible population.

No doubt that thermometric discomfort can cause stress even when associated with increasingly cold temperatures. Global warming, indeed, was also associated to some particularly cold winter months (especially January) in recent decades, but the general trend of Italian winters is nevertheless towards increasing temperatures (Brunetti et al., 2006). Months like November to February were found to positively associate to a higher risk of suicide among males than among females: the effect is in a medium to a large range, according to Cohen (1988), whether deviant points are included or not. Nevertheless with males we found an anti-correlation between temperatures and a lower number of suicides in the month of January. It may be that this finding reflects the role of surveillance on the risk of suicide. Chew and McCleary (1994) suggested that surveillance, together with accessibility to lethal means, is a key element in suicide: they state that intense routine surveillance can lower suicide risk even when lethal means are easy to come by. Surveillance of mentally ill subjects may decrease in summer, as family and friends spend more time out-of-doors, and this may contribute to the summer peak of suicides. Conversely in cold months like January, lower temperatures are likely to induce people to stay at home. As a result people suffering from mental disorders, especially the elderly or adolescents, are more likely to get an enhanced surveillance by their families and/or close friends. The most remarkable impact of this process on males depends on the fact that males normally enjoy a less developed social support network than females: an increase in surveillance level may as well have a positive impact on males, but not so on females, who already experience a more complex social support and surveillance network. Indeed, a well integrated social network is a relevant factor that protects against the lethal outcome of suicide attempts: in a study concerning black American women, Nisbet (1996) found that black women, though attempting suicide at about the same rate as white women, are less likely to complete suicide primarily by their larger kinship and friendship networks. The different sensitivity of women to climate and seasonal influences on suicidal behaviour is a well-known reported finding (Preti, 2002), adding to a long list of differences by gender in the risk of suicide: women are more likely to attempt suicide, but men are more likely to complete suicide; men also tend to use more violent means, women, instead, are more likely to take an overdose and then can be salvaged (Canetto and Sakinofsky, 1998; Joiner et al., 2005). Differences by gender and age also exist in the distribution of mental disorders leading to suicide (Brady and Randall, 1999; Paris, 2004; Baldassano, 2006). We lack data on age band and method of suicide for the entire period, so we were unable to test more in depth the nature of the different sensitivity to global warming of females compared to males.

On the whole, a more general effect of increasing temperature on the risk of suicide cannot be excluded,

with an impact on both the risk of developing a mental disorder and the chance that impulsive outbursts result in a sudden suicide attempt (Wehr and Rosenthal, 1989; Maes et al., 1994; Lambert et al., 2003). The links between temperature and suicides in November, for example, might be a reflection of lower sunlight exposure, a risk factor for the onset of a subgroup of major depression syndromes that recur on a seasonal basis (Wehr and Rosenthal, 1989). Typically, in Italy November is the rainiest and cloudiest month, and the rank order correlation between the index of cloudiness and suicide rates is high in both males ($r=0.24$) and females ($r=0.36$) (details of data not shown).

An even more indirect effect of recent climate changes may have affected suicide mortality. As correctly pointed out by an anonymous reviewer, the same mechanisms affecting climate (anthropogenically-induced multi-pollution) are also affecting human health, as seen in the increased incidence of cancer in younger people and in the earlier onset of neurological disease in adults in the Western world (Pritchard et al., 2004). This may, as well, increase the risk of suicide, which is itself enhanced in these illnesses (Harris and Barraclough, 1994; Zeller, 2006), leading to a spurious correlation with anomalies of temperature that are interrelated with all the other effects of multi-pollution. Moreover, the waste of natural landscapes and the deterioration in flora and fauna related to multi-pollution and its effects on the natural world might further reduce the sense of satisfaction and happiness in people, excursion in natural environments representing an opportunity to buffer the negative stress of urban life. Various indices of happiness have been found related to suicide mortality at both individual and group level (Koivumaa-Honkanen et al., 2001; Bray and Gunnell, 2006).

It is worth mentioning the somehow speculative character of our interpretation of results, to be weighted against other possible contributing mechanisms. There is suggestive evidence that suicide is more openly reported than in previous times in "Catholic" cultures: as an effect of a progressive decrease of the, otherwise pervasive, influence of the Catholic Church, so-called "secularization", the stigma attached to suicide appears to have lessened, favouring a more reliable reporting of deaths by suicide (De Leo et al., 1997; Chishti et al., 2003; Pritchard and Hansen, 2005). Of course this does not necessarily "explain" the most recent increases in suicide rates, rather it is a factor that needs to be considered. Moreover it cannot be denied that changes in weather affect economic activities, particularly in a complex society such as Italy, where agriculture still competes with industry in providing part-time occupation for the most disadvantaged, and where a large fraction of economy depends on tourism, which is highly sensitive to weather and climate variations. However, all these effects would have produced smooth variation in suicide risk, because they have occurred progressively rather than abruptly like the summer heatwaves occurred 2000 to 2003, and they should have been removed by the Gaussian low-pass filtering procedure (Adelmann, 1997).

Other limitations have to be taken into account in considering our explanations of the results. On the whole, the effects of global warming are more likely to be highlighted using weekly or daily data rather than relying on monthly aggregate figures. The use of monthly data, indeed, is a major limitation of this study, but unfortunately more detailed data on suicide were not publicly available in Italy. We could not analyze the impact of environmental temperature on suicide by age as well: again, information was not available for the whole time interval.

5. Conclusion

Climate change may have unforeseen consequences on health. Improving the ability of communities to adjust to temperature changes by implementing public health interventions may play an important part in preserving the wellness of the general population, and also in limiting the worst consequences of suicidal behaviour. Interventions aimed at reducing anthropogenic effects on climate, such as reducing air pollution and improving energy allocation, are strategic (Haines et al., 2006); however, short-term interventions can be effective as well, such as improving the buffering capacity through technology (air conditioning) and implementing a weather-watch warning system (Patz et al., 2005). Improvements in infrastructure, technology, and general health will have an important bearing on what can be realistically expected concerning future climate changes (Haines et al., 2006; Carson et al., 2006).

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