

# Influence of climatic factors on suicide rate in Split in 2011-2015

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**Master's thesis / Diplomski rad**

**2017**

*Degree Grantor / Ustanova koja je dodijelila akademski / stručni stupanj:* **University of Split, School of Medicine / Sveučilište u Splitu, Medicinski fakultet**

*Permanent link / Trajna poveznica:* <https://um.nsk.hr/um:nbn:hr:171:560690>

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*Download date / Datum preuzimanja:* **2024-07-14**



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**UNIVERSITY OF SPLIT  
SCHOOL OF MEDICINE**

**Philipp Schubert**

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IN SPLIT IN 2011 – 2015**

**Diploma thesis**

**Academic year:  
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Kristijan Bečić, MD, PhD**

**Split, July 2017.**

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*I thank my mentor, Kristijan Bečić, MD, PhD, for his guidance and help throughout the process of writing this thesis.*

*I also would like to thank my family and friends for their support during this time.*

*Thank you Pauline, without your caring support this would not have been possible.*

## **1. INTRODUCTION**

## **1.1. Suicide and impact on Health and Society**

### 1.1.1 Recent Data on global incidence of Suicide

Self-harm in the form of suicidal behavior is common in the general population and despite its devastating impact on families it also exhibits long lasting effects on communities and economies. According to WHO, there were approximately 788.000 completed suicides in the year of 2015. This indicates an annual average standardized suicide rate of 10.5 per 100.000 population (1). It is estimated that a far bigger number of attempted suicides take place because data is limited to only hospital-treated incomplete suicides. There are indications that for every completed suicide there are twenty attempts to end one's life (2). Suicide attempts occur through all age groups but they are lowest in persons under the age of 15 and highest in those aged 70 years and older (1). In the group of adolescents and young adults in the age between 16 and 29, suicide represents the second most common cause of death worldwide, after traffic accidents, accounting for 8,5% of the overall mortality (1). Among adult population in the age of 30 to 49 years, suicide accounts for 4.1% of all deaths ranking it the fifth leading cause of death (1).

Despite these global trends, suicide rates are highly variable in different regions of the world. For example, in low-and-middle income countries young adults and elderly women have a much higher risk to commit suicide compared to high-income countries where middle-aged men count as high-risk group (2). Also, the incidence of suicide can vary between different areas, the age-standardized suicide rates ranges from 0.4 to 44.2 per 100 000 globally (1). High-income countries and Low-and-Middle-Income-Countries of the South-East Asia Region show a suicide rate of 17.6% and 16.6% respectively among young adults aged 15–29 years and represent the leading cause of death for both sexes (2).

Between the years 2000 and 2012, the age-standardized suicide rate was reduced by 26% (23% in men and 32% in women). This drop in rates happened in all regions of the world except in low-and-middle-income-countries in the African region and among men in low-and-middle-income-countries in the eastern Mediterranean Region (1).

Looking at its relative contribution to all violent deaths, for example interpersonal violence, armed conflict etc. globally, suicides account for 56% of all violent deaths with a higher incidence in women (71%) towards men (50%) (2).



### 1.1.2. Socioeconomic Burden

Suicide is not only an extreme emotional burden on the victim's social environment. It also has considerable costs. According to a cost analysis of Shephard et al., cost of suicides and suicide attempts in the United States in 2013 is estimated to \$58.4 billion based on reported numbers alone (3). Major part of it represents indirect costs in the form of lost productivity with 97,1%. Considering that not all suicides have been reported properly, total cost was estimated to \$93.5 billion or \$298 per capita (3).

Suicidal behaviour can be complete resulting in a fatal injury, or incomplete resulting a nonfatal injury. Each type produces costs, either directly, related to injury treatment or indirect economic costs, which are mainly productivity losses from premature death or lost time from injuries. Direct costs are, for example, those for medical care (emergency medicine and hospitalization), transport, investigation by medical examiners or coroners, general and speciality physicians' care and follow-up treatment. Indirect costs or economic costs represent future salaries and wages, fringe benefits and the value of household productivity lost (3).

Despite the costs that are calculated out of the loss of the victim itself, the emotional impact of suicide to the familial and closer interpersonal environment has to be considered as well, because it may alter their productivity thus contributing to indirect costs. Especially in incomplete suicides, families have a role in caring for a suicidal family member and in the prevention of future suicide (4).

### 1.1.3. Preventive Measures

Looking at these numbers it becomes evident that it is of great interest to improve scientific evidence about factors determining suicidal behavior, because suicide is a preventable death.

So far, suicide rate has decreased in the recent years (26% between 2000-2012), except in the before mentioned areas. The reason for this is not quite clear. Possibly, improvement in global health over the past decade can be at least partially held accountable for this development, since between the years 2000 and 2012, global age-standardized

mortality rate for all causes decreased about 18 %. Despite these positive figures, there is still a lot of work to be done to reach the 2013-2020 WHO Mental Health plan, which aims at reducing the global standardized suicide rate by 10% in the year of 2020 by intensifying preventive measures and incorporating them into national suicide prevention plans (2).

However, what are possibilities to decrease the odds for an individual to kill him or herself? According to the USI-model, intervention methods can be characterized as universal, selective and indicated (5).

An universal prevention method approaches an entire population, i.e. a nation, state, local county or community, school or neighbourhood. These programs intend to reduce suicide risk by removing barriers to access health care, enhance knowledge about supporting suicidal individuals and increase social support and coping skills. With these aims those methods include public education campaigns, means of restriction to methods, education programs for the media about the way of reporting about suicide and school-based crisis response plans and teams (6).

School based mental health and suicide awareness programs with or without combined screening show promising results in preventing suicides (7). Obviously, restriction to access of lethal means of suicide shows strong association with decreased suicide rates, and is a major part of national suicide prevention plans (7).

Selective prevention strategies focus on subpopulations with increased risk to commit suicide in the form of screening programs, gatekeeper training for caregivers, support and skill-building groups, and enhanced accessibility to crisis services and referral sources (6). Since high-risk subgroups include individuals with mental disorders, pharmacologic interventions play an important role as preventive measure (8). A variety of studies show positive results of pharmacologic treatments. Lithium for example appears to be effective in the therapy of behavioural disorders and clozapine can be used in schizophrenia. But most recent meta-analysis of randomized-control trials could not find statistically significant correlation between lithium therapy and decreased suicidality despite decreased numbers of suicide in those groups (9).

Indicative prevention methods target persons that already engaged in self-destructive behaviour. Possible approaches in those groups are cognitive behavioural therapies and pharmacotherapy. But although recent data showed an overall lower number of suicides compared to control group, the differences were not statistically significant (8). In contrast to

that, WHO brief intervention and contact initiative (BIC) which provides a psycho-education session and follow-up of 9 phone contacts over an 18-month period to persons who attempted to commit suicide, showed very promising results with a highly reduced number of suicides in these groups (8).

To conclude, these elements appear to be crucial in national suicide prevention strategies. But to ensure the effectiveness of such programs, these different approaches most certainly must be combined and efforts have to be made in different levels of our society. First of all, the government can introduce laws to restrict the access to means of suicide. Moreover, increasing funds of health-care services can be helpful in order to improve healthcare to those in risk. For example, patients with mental disorders or alcohol abuse, since early identification and treatment of such subgroups are crucial.

In addition to that, through media campaigns, awareness in communities can be improved and they can be integrated in support and follow-up care of vulnerable subgroups. This can be especially helpful in countries with limited financial abilities.

## **1.2. Risk Factors**

In current literature, there is a considerable amount of data connecting a great variety of factors with an increased risk to commit suicide and many models are hypothesized to explain suicidal behavior (10). There is consensus that the tendency of a person to end his or her life is of multifactorial nature and reasons can be found in biological, psychological, sociocultural, demographic and environmental areas and frequently these reasons act cumulatively.

### **1.2.1. Cultural and societal risk factors**

Cultural and societal factors, like attitudes, beliefs and norms, as well as organization of health-care systems, can play an important role in development of suicide ideation. Barriers to accessing health care may negatively influence suicidal tendencies. Due to their complexity, it can be challenging for people with low health literacy in general, and especially low mental health literacy. Moreover, possible stigma for help-seeking behavior

because of suicidal behavior and mental disorders may add to this barrier and prevent patients from getting timely and effective access to health care (11).

The access to means of suicide is considered a major risk factor for suicide. Availability of or direct access to means like pesticides, firearms, height, railway tracks, poisons, medication, sources of carbon monoxide or other poisonous gases is directly correlated with increased suicide risks. The preference and availability of different means of suicide depend on local and cultural contexts, which also has to be considered (12).

Extensive and inappropriate media coverage about suicide was also found to have an impact on suicidality in the form of so-called copycat suicides or Werther effect (13). Despite general agreement in the journalistic field about this topic, there are enough examples where media extensively cover celebrity suicides, report unusual methods of suicide or suicide clusters, show pictures or information about the method which was used or normalize suicide as an appropriate measure in response to crisis or adversity. Vulnerable groups exposed to models of suicide have been shown to have an increased suicidality (14,15).

But not only media coverage is in the focus of suicide prevention, the internet and social media play an important role in suicide communications. As a leading source of information, it also contains accessible sites that are not underlying any press codex and therefore may show inappropriate portrayal of suicides. Therefore, internet sites and social media most probably facilitate and incite suicidal behavior (16).

### 1.2.2. Community risk factors

Disaster, war and conflict paradoxically show decreasing suicide rates immediately after the incident. This can be explained by the need of intensifying social cohesion in those times of need. But data is inconclusive concerning this with research pointing into both directions (17).

Stresses of acculturation and dislocation represent significant suicide risk with impact on a variety of vulnerable groups, i.e. indigenous peoples, asylum-seekers, refugees, persons in detention centers, internally displaced people and newly arrived migrants. Native Americans in the USA, Inuit's in Canada, Australian aboriginals as well as aboriginal Maori in New Zealand all exhibit much higher suicide rates compared to the rest of the local

population (18,19). Young people, especially young males, seem to be among the most vulnerable groups in the world (20).

Loss of territorial, political and economic autonomy often result in negation of native culture and language. In consequence, feelings of depression, isolation and discrimination are generated and accompanied by resentment and mistrust of state-affiliated social and health-care services (19).

Discrimination against subgroups can lead to the continued experience of stressful life events such as loss of freedom, rejection, stigmatization and violence that may evoke suicidal behaviour. Examples for subgroups at risk are people with non-heterosexual orientation, prison inmates, those who are subject to bullying, cyberbullying and peer victimization and refugees, asylum-seekers and migrants (21-25).

### 1.2.3. Interpersonal risk factors

A person's interpersonal life plays an important role in one's psychosocial well-being and can have influence on suicidal behaviors. Sense of isolation and lack of social support for example, were shown to contribute to increase suicide risk, and also are important components of contemporary models of suicidality (26). Trauma or abuse during the life significantly increases emotional stresses, may lead to depression, and can ultimately trigger suicidal behaviours in people who are already vulnerable.

There is considerable body of data showing strong association between the occurrence of negative life events during childhood, i.e. physical, sexual or emotional abuse, family violence or parental illness, divorce or death and suicidal behavior. Moreover, these adverse events showed an exposure-response relationship in those studies (27).

One of the most important stressors represent sexual and physical abuse during childhood. Studies showed that this population appears to be especially vulnerable and exhibits significant and persistent suicidal behavior during childhood and adolescence. The association between childhood adversities and suicidality decreases with age (28).

In addition to that, negative life events during adulthood do also play a role in the development of suicide ideation. Although different types of events appear to be influential, the exact mechanism is still unclear. There is suspicion that a combination of hypothalamic-

pituitary-adrenal axis abnormality, and again psychological disturbance may influence response to stressful life events (29). Relationship conflict, discord or loss represents those stressors that can ultimately lead to suicide ideation, attempt, and possibly completion.

#### 1.2.4. Individual risk factors

Intrinsic factors that may contribute to a person's tendency to self-harm and suicidal behavior are summarized as individual risk factors. Namely, these are genetic and biological predisposition, mental or physical health disorders and a person's personality and specific personality traits. A previous suicide attempt is considered to be highly predisposing to a second attempt (30-33).

In addition to that, family history of suicide has a strong implication to increase a person's risk to commit suicide. The tragedy of losing someone close to you often represents an overwhelming life event, and has a variety of effects on the personality. Despite grief, there may also be feelings of guilt, stress, shame, anger, anxiety and distress to family members and loved ones. However, most importantly, family dynamics may change, and usual structures of support can be disrupted. Moreover, stigma may prevent help seeking of the persons and avoid others from offering support. Therefore, persons experiencing the suicide of a family member are at self in risk to commit suicide (34,35).

Substance abuse disorders are often connected with increased risk to commit suicide (36). In psychological autopsy studies between 19% and 63% of all suicides suffered from substance use disorders, most commonly from alcohol abuse (37). Besides alcohol, there is evidence that links other substances like nicotine, heroin and cannabis to increased suicidality (38-40).

According to psychological autopsy studies of suicide victims, in high-income countries, mental disorders were present in up to 90% of people who died by suicide, with depressive disorders having the highest correlation (33). In addition to that, Henriksson et al. speculated that up to approximately one quarter of all suicides happened in an acute psychiatric disorder which includes psychotic traits (41). On the other hand, psychiatric disorder patients rarely become suicidal. Less than 5 % of patients admitted with affective disorder die by suicide (42).

Personality traits are also considered to be influential since they are more or less stable in adulthood, often are biologically explainable and influence behaviour, emotion and cognition. Namely, these are hopelessness, impulsivity and perfectionism (43). In addition to that personality dimensions, especially high levels of neuroticism, and low levels of extroversion are associated with suicidal behaviour (44,45).

Moreover, a variety of cognitive factors were identified to contribute to suicidal behavior. Cognitive rigidity, rumination, thought suppression and autobiographical memory biases among many others, are considered to be risk factors (46-49).

Despite the fact, that the presence of a psychiatric disorder or a specific personality trait can be considered a risk factor for suicidal behaviour, they have little predictive power, and do not contribute to explain why people kill themselves. That is why it would be useful to identify more specific markers in order to make suicide more preventable.

But in order to improve prevention of suicides, it is not only important to identify risk factors which lead to suicide, it is also important to describe the occurrence and possible peaks in frequency. This offers the opportunity to make such events predictable, and therefore preventive measures can be intensified during those times (50).

#### 1.2.5. Seasonality

One factor in particular is seasonality, meaning that suicide seems to occur along seasonal patterns during a year. This may be explained by the influence of seasonal and cyclic patterns on circadian rhythms, which impact on biological and psychosocial regulation of human behavior (51,52). Against common suspicion and rather surprisingly, there are different studies showing that numbers of completed suicide peak in spring and summer time and appear to be less likely in winter (53,54). The same effect seems to be applicable to suicide attempts, but in this case further research is necessary (55).

According to Chew and McCleary et al. seasonality of suicidal behavior is mainly influenced by bioclimatic, as well as socio-demographic factors (56). This spring peak for example can plausibly be explained by increased sunlight exposure during these seasons that may alter biological mechanisms via serotonin and melatonin biochemical pathways (57). Moreover, seasonality is highly dependent on the geographic location. It is most pronounced

in higher latitude countries like Greenland and Norway, also persisting until the lower latitudes but is less pronounced in equatorial regions (58,59).

Despite some convincing evidence concerning seasonality there are still questions about which kinds of other bioclimatic factors possibly influence suicidality and if they do, in what way.

### **1.3. Climatic influence on suicidality**

#### 1.3.1. Climatic parameters and health

The hypothesis that weather influences our health dates back to the old Greek, 3000 years ago (60). Over the years, the influence of climate and climate changes on several of diseases has been suggested. Connections between climatic factors and many diseases have been established and proven so far. These are for example multiple sclerosis, coronary heart diseases, ischemic stroke and migraine (61-64).

#### 1.3.2. Climatic parameters and suicide

Concerning the correlation of weather with suicide, there is consensus that weather can have influence on mortality rate as well as a contribution to suicidality, but so far data does not succeed in aligning particular weather conditions with self-harm often offering inconclusive evidence varying from no, beneficial, harmful to mixed associations (65).

Topics of interest of recent research was mostly temperature with the result that warm weather leads to a modest increase in suicide rate (66,67). Other factors include increased sunlight exposure which appears to be promoting suicidal tendencies, rainfall and cloud coverage on the other hand seem to be protective (68). Most recent studies look at other environmental factors like pollen pollution. Increased pollen exacerbated allergic disease which were found to increase suicidality (69). Climatic factors like storms or local phenomena were not profoundly examined and there is considerable lack of data concerning these. Overall, with upcoming climate change and climate becoming more and more extreme, the detection of climatic factors which may precede and influence suicide rates becomes more and more important.



But, problems persist to link specific factors to suicide mortality. It is very likely that this correlation is not unifactorial but more multifactorial with a significant local sociocultural influence.

## **1.4. Weather Phenomena and sociocultural impact in Split-Dalmatia County**

### **1.4.1 Climate in Split-Dalmatia**

Split Dalmatia County as part of the Croatian coast is in a circulation of mid-latitudes with its characteristic weather conditions (70). In the warm period of the year, the coastal regions come under the influence of the subtropical zone because of the Azorean anticyclone influence that prevents outbreaks of cold air to the Adriatic. Since the most important climatic modulator in this area is the sea, the climate can be referred to as maritime. In addition to the sea, the mountains of Gorski kotar in the north-west and the Dinarides in the south, shape the weather in Dalmatia by facilitating the formation of low-pressure systems (70).

In the summer period, the area mainly remains in a zero pressure gradient field of about 1015 hPa with constant, clear weather. Main winds, due to the general pressure gradient in the Mediterranean and the position of the Adriatic Sea, are north-western winds, so called Etasians, which are gentle in the open sea and moderate in middle Adriatic area. In coastal areas and larger islands, local daily periodic circulation develops as a consequence of unequal warming and cooling of land and sea surfaces during the day and night, resulting in daily sea breeze and nightly land breeze. These changes contribute to a regular exchange of air characteristics, a high amount of turbulences, a homogenous spatial distribution of meteorological parameters and consequently, the weakening of weather extremes (70).

During the cold part of the year in which those mitigation factors do not prevail, the weather becomes highly dependent on local conditions (70). According to the Köppen climate classification most of Croatia is considered to be a temperate rainy climate. In the coastal area, the warmest month of the year has an average temperature above 22°C and more than four month a year have a monthly average temperature higher than 10°C (70).

On the islands and the inland parts of Split-Dalmatia county there is prevalent Mediterranean climate, meaning their climate is mainly characterized by a hot dry summer and rainy winters. The driest month of the year shows less than 40 mm of precipitation that is less than a third of the amount in the rainiest month in the cold season. Generally, Dalmatia is considered to have a humid climate (70).

#### 1.4.2 Climatic phenomena

Especially two specific weather phenomena are of importance, namely bura and jugo, which are strong winds that can have a great impact on everyday life. Meteorologically, bura consists of a strong north-east to north-north-east catabaric wind, mainly occurring during winter months. It represents strong, gusting winds reaching up to 250 km/h, flowing from polar high-pressure systems over the Croatian main land to warm low-pressure systems residing over the Adriatic Sea. Bura is not confined to the Dalmatian coast alone. Along the 30-degree latitude in areas with similar geological features, there are several winds with the same features. These are for example the Santa Clara in Southern California, Orishi in Japan and the Bohemian wind in the Ore Mountains (71).

Jugo on the contrary is a southerly wind consisting of a warm air mass which is pulled northwards by low pressure systems over the lower Mediterranean Sea. Originating from north African deserts it often carries desert sand with it which tends to rain down after traveling over the sea where it gains humidity. It can reach velocities of around 100 km/h and occurs most frequently during spring and autumn (70).

To sum up, jugo presents as a warm, humid wind with low visibility and bura is cold, dry, very strong with high visibility.

#### 1.4.3 Cultural Perception of weather in Split-Dalmatia-County

Along the Adriatic coast, the climate plays an important role in the population as it is a nation with a long tradition of sailing and fishing, highly dependent on weather conditions. As diametrically opposite jugo and bura winds are from a metrological point of view, the same is true for the cultural perception in southern Croatia. Jugo is commonly accused of causing body ache, depression and grumpiness. In contrast, bura is welcomed. Because of its

dryness, it helps drying the traditional dish “pršut”, which is dried ham from pork meat (prosciutto). There is a saying without bura there is no good “pršut”. In addition to that, as a sea-wind, it blows salt onto the shores and with animals eating on the grass it adds to the unique flavor of dairy products like cheese.

Apart from those subjective mood swings of the Dalmatian population, one can also find evidence in ancient constitution of the City of Dubrovnik, the southernmost city of Croatia. It postulates that no laws should be made in those times because the weather is influencing the mind too much. In addition, crimes were not prosecuted since they could be excused by the bad mood the weather was producing (72).

### **1.5. Recent data on suicide in Split-Dalmatia County**

In 2015, 739 Croatian citizen committed suicide. WHO ranks the Republic of Croatia as 59<sup>th</sup> Country worldwide with a standardized suicide rate of 12.2 per 100.000, which is slightly above the global average (1).

During the year of 2015, 35 people took their life in the city of Split. With its population of 230.000 inhabitants, this results in a suicide rate of 15.3 per 100.000 which is above Croatian average (1).

## **2. OBJECTIVES**

We hypothesized that climatic factors may present an influential factor on suicidal behavior in the area of Split. With identifying those factors, it is possible to use the predictability of weather factors to improve suicide prevention by describing high risk periods in which preventive measures can be intensified and therefore effectivity is increased.

### **3. METHODS**

### **3.1. Mortality Data**

In this study, main focus was on completed suicides in the general population in the city of Split between 1<sup>st</sup> of January 2011 and 31<sup>st</sup> of December 2015.

Data containing information about the date, sex, age and method used was obtained from Croatian Institute for Public Health in Zagreb.

Codes x60-x84 from international classification of diseases-10 were used for the analysis.

### **3.2. Meteorological Data**

Meteorological data was obtained by the Croatian national meteorological and hydrological service DHMZ. Information about weather changes was collected in the weather station Split, Marjan.

Following parameters were taken into account:

- A) Daily mean temperature above or below monthly average
- B) Wind speed and direction (Bura at NE, NNE and ENE; Jugo at SSE, SE, ESE)
- C) Hours of sunshine above or below monthly average
- D) Barometric pressure above or below of monthly mean pressure
- E) Cloud coverage above or below monthly average

### 3.3. Statistical Analysis

Numbers of completed suicide were compared with above mentioned variables on a day-to-day basis. In order to make this study comparable to others, we adjusted our methodology to the most recent studies. Accordingly, any seasonal effects were removed, since this appears to be a frequent shortcoming in methods examining the effects of weather.

Climate often underlies seasonal variation. In summer, obviously, there is a higher daily mean sunshine duration compared to winter. The same is true for atmospheric pressure, because weather systems appear to be more stable in summer. Also, bura and jugo tend to occur more in different seasons as previously mentioned. Except the weather variables there are also other factors like holidays or the end of a scholastic year for example, which may contribute to seasonality of suicide and therefore may influence the results. Therefore, seasonality combines all these different factors and makes it difficult to evaluate the effect of one particular weather factor on suicide mortality and therefore it was decided to correct for seasonality (73).

In order to do so, a new time series  $x'_t$  was created for each variable represented by  $x_t$ . For example, each value of daily hour of sunshine or daily number of suicide represented by  $x_t$ , was repeatedly subtracted by its values from the year before  $x_{t-365}$ .

$$x'_t = x_t - x_{t-365}$$

After differencing, Pearson Correlation coefficients were calculated to demonstrate the suggested connection between climate factors and suicidal behavior. All calculations were repeated distinguishing between male and female suicides. For statistical analysis IBM SPSS version 1.0.0.580 was used. Two-tailed P-values  $< 0.05$  are considered statistically significant.



## **4. RESULTS**

Within the observed 5 years, there were 214 suicides in total, 152 males and 62 females, in the county of Split-Dalmatia. Table 1. shows association of weather factors with numbers of all suicides between 2011 and 2015. Figure 1. illustrates Pearson correlation coefficients for each weather factor. Negative correlation is shown in red, positive correlation in blue. The strength or weakness of the association is indicated by the size of the bar.

Table 1. Association of weather factors with numbers of all suicides between 2011 and 2015

Weather Factor	Correlation coefficient	P*
Mean Temperature (C)	0.03	0.892
Mean rel. Humidity (%)	-0.028	0.231
Mean Atmospheric pressure (hPa)	-0.001	0.974
Mean Insolation (hrs)	0.046	0.049
Cloud coverage (%)	-0.049	0.035
Windspeed (Bft)	-0.001	0.954
Jugo (yes/no)	0.004	0.851
Bura (yes/no)	0.033	0.159

Data are presented as Pearson Correlation coefficients.

C - degree Celsius, hPa – hectopascal, hrs - hours per day, Bft – beaufort.

After removal of the seasonal effect, statistically significant positive correlation of mean sunshine duration ( $r= 0.046$ ,  $P= 0.049$ ) on the day of the event, and a negative correlation of cloud coverage ( $r= -0.049$ ,  $P=0.035$ ) was found.

Mean relative humidity showed the strongest negative correlation (next to cloud coverage) but with  $P=0.231$ , not statistically significant. Figure 2. illustrates the course of daily relative humidity throughout the year, indicated by the black line, together with numbers of suicide depicted by the red dots. Mean temperature and northerly winds in the form of bura showed correlation coefficients of  $r= 0.03$  and  $r=0.033$  respectively, but similar to humidity, these connections are not significant ( $P=0.892$  and  $P=0.159$ ) and very weak.

Wind-speed, mean atmospheric pressure and if there were southerly winds showed no correlations with values close to zero.

Figure 3. depicts the values of barometric pressure over one year together with daily numbers of suicides. Although it seems that there is some connection, especially when values of atmospheric pressure are peaking in either direction, this association is not significant.

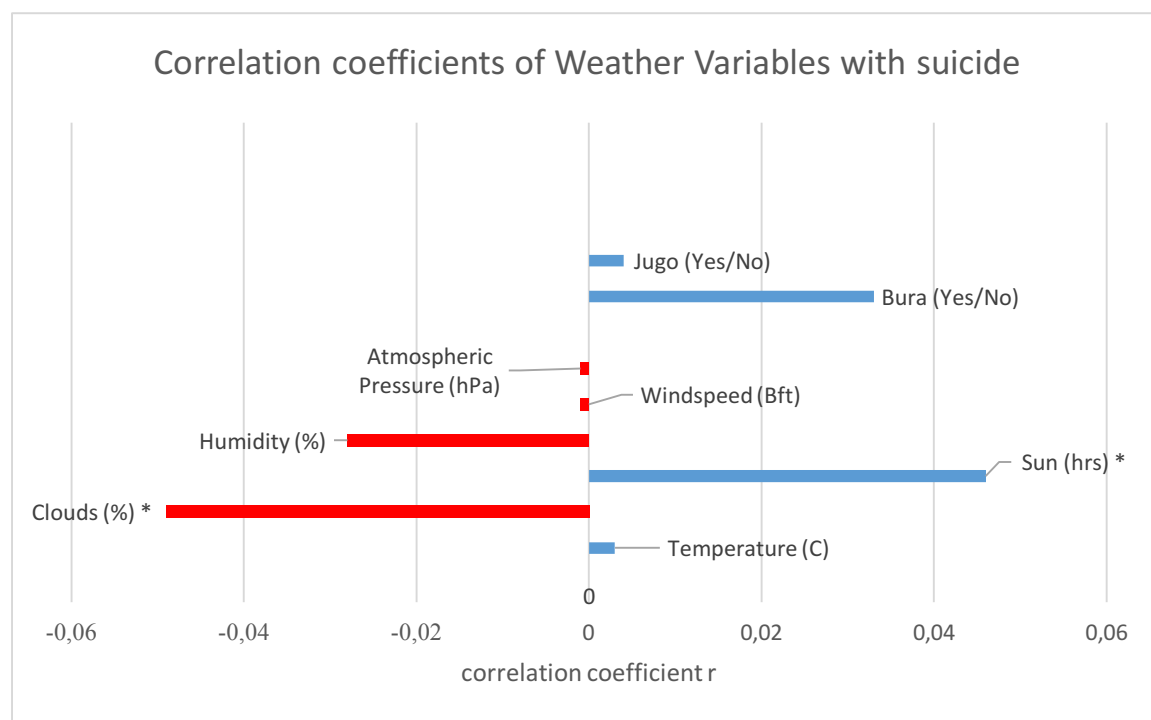


Figure 1. Correlation coefficients of each investigated weather factor depicting direction of association with suicide

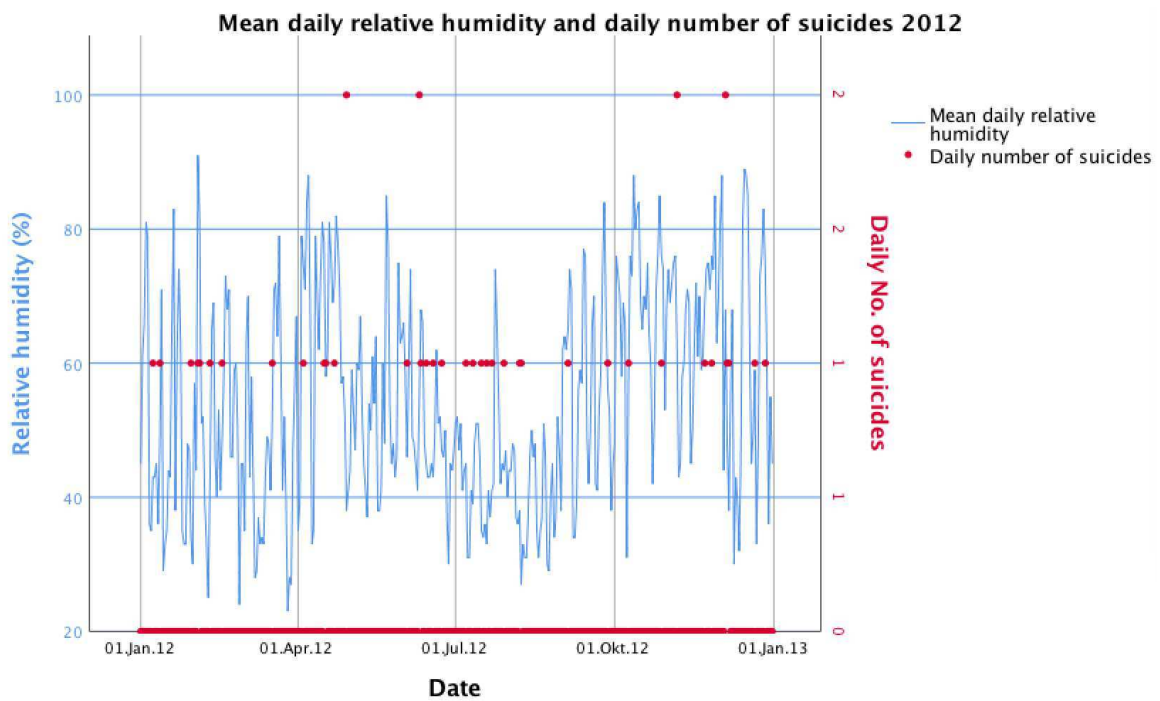
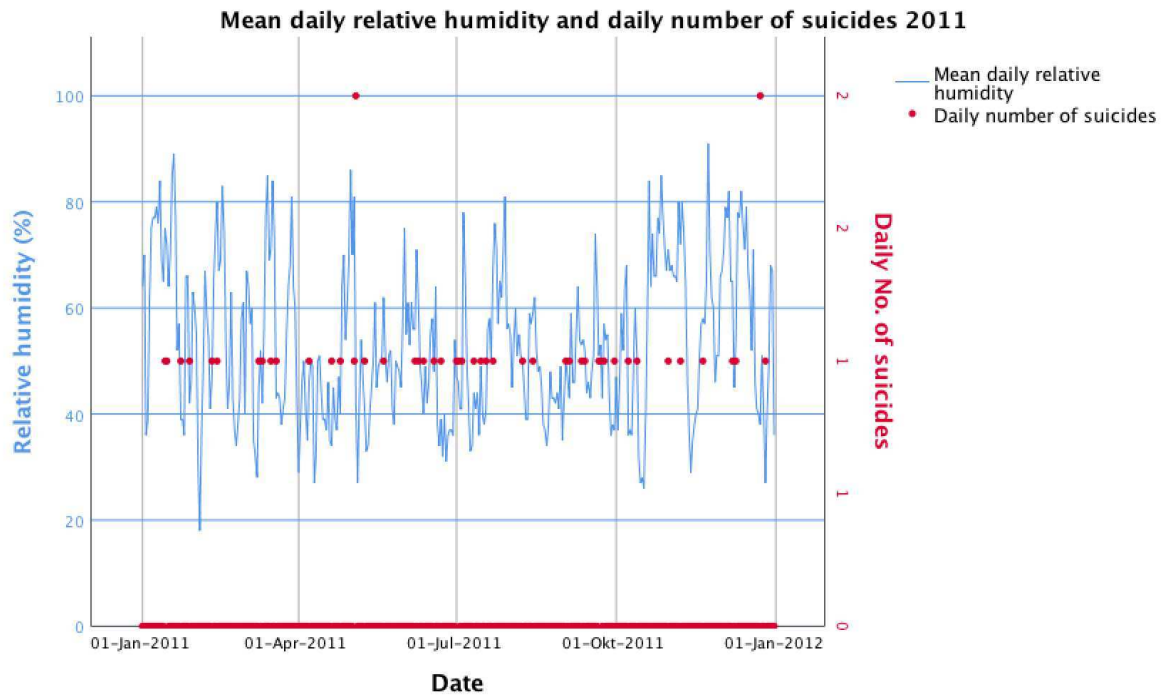


Figure 2. (Part 1/3). Mean daily relative humidity and daily number of suicides between 2011 and 2015

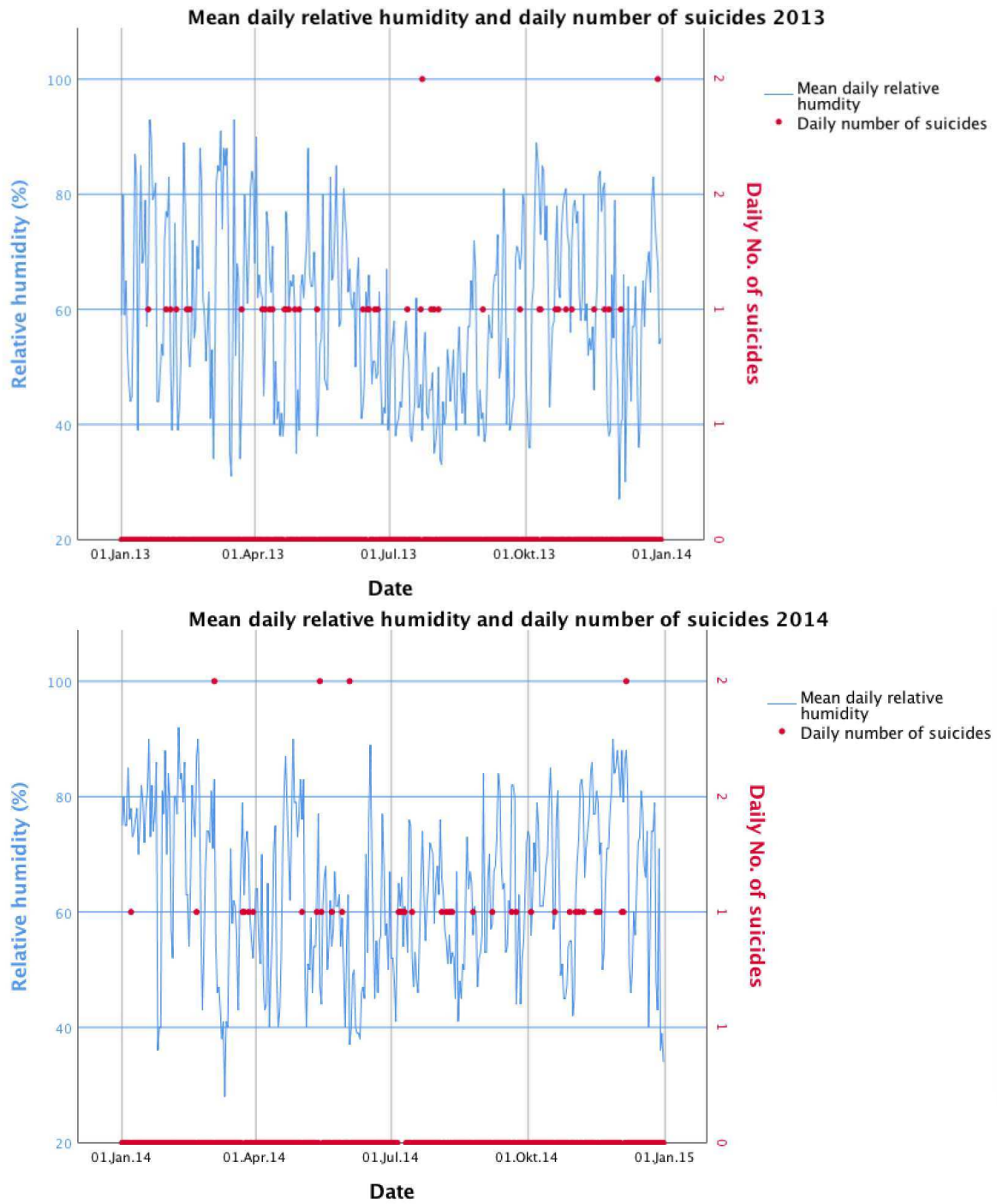


Figure 2. (Part 2/3). Mean daily relative humidity and daily number of suicides between 2011 and 2015

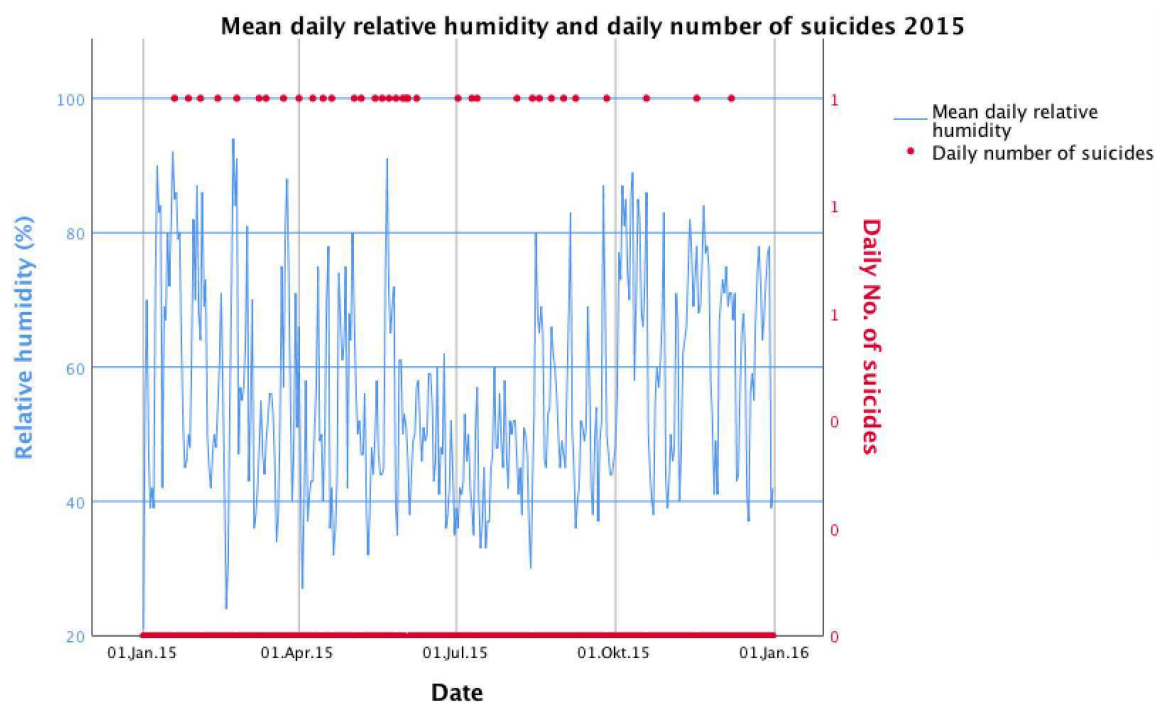


Figure 2. (Part 3/3). Mean daily relative humidity and daily number of suicides between 2011 and 2015

Table 2. Association of weather factors with numbers of male suicides between 2011 and 2015

Weather Factor	Correlation coefficient	P*
Mean Temperature (C)	0.005	0.845
Mean rel. Humidity (%)	-0.037	0.119
Mean Atmospheric pressure (hPa)	-0.002	0.941
Mean Insolation (hrs)	0.057	0.015
Cloud coverage (%)	-0.052	0.027
Windspeed (Bft)	-0.007	0.764
Jugo (yes/no)	0.011	0.626
Bura (yes/no)	0.038	0.108

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Data are presented as Pearson Correlation coefficients.

C - degree Celsius, hPa – hectopascal, hrs - hours per day, Bft – beaufort.

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When splitting the complete sample into male and female suicides, those correlations were only reproducible in the former ones. As shown in Table 2, there is a positive correlation with mean sunshine on the day of the event ( $r= 0.057$ ,  $P= 0.015$ ), and similar to the complete sample, negative correlation with cloud coverage ( $r=-0.052$ ,  $P= 0.027$ ). With no difference to the complete sample, despite not being statistically significant, the directions of the other variables did not change.

As mentioned before and illustrated in Table 3, looking at data of only female suicides, the results from the complete sample were not reproducible.

Table 3. Association of weather factors with numbers of female suicides between 2011 and 2015

Weather Factor	Correlation coefficient	P*
Mean Temperature (C)	-0.004	0.854
Mean rel. Humidity (%)	0.024	0.296
Mean Atmospheric pressure (hPa)	0.030	0.895
Mean Insolation (hrs)	-0.030	0.197
Cloud coverage (%)	0.002	0.932
Windspeed (Bft)	-0.028	0.235
Jugo (yes/no)	-0.023	0.630
Bura (yes/no)	-0.011	0.334

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Data are presented as Pearson Correlation coefficients.

C - degree Celsius, hPa – hectopascal, hrs - hours per day, Bft – beaufort.

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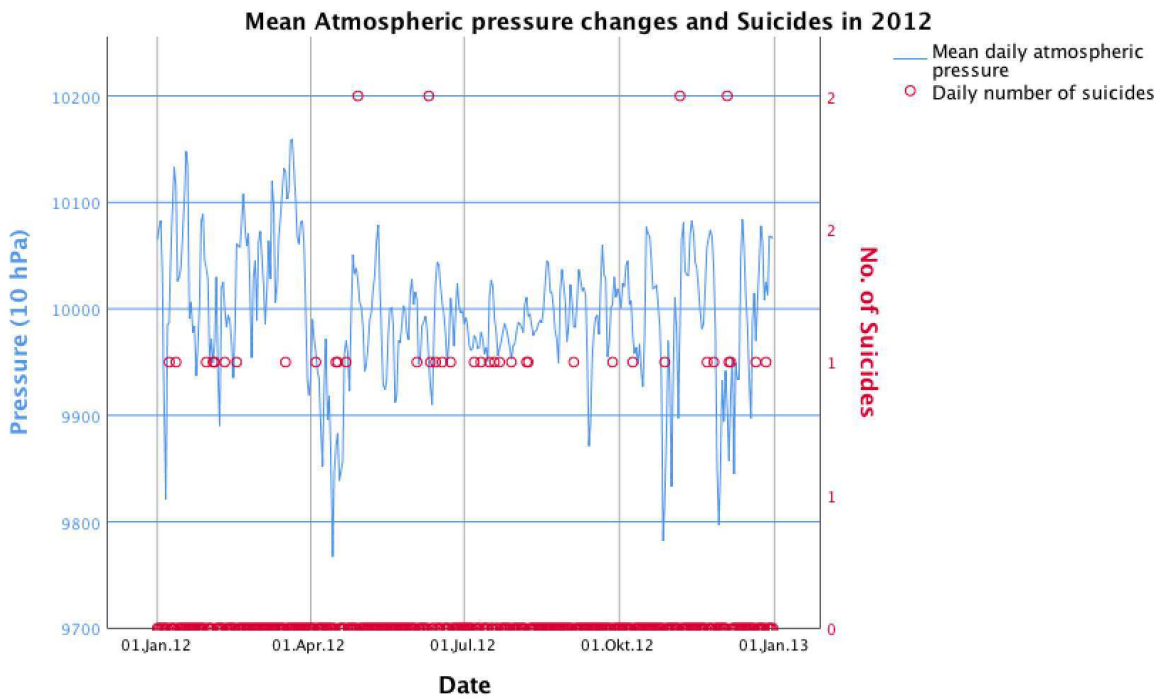
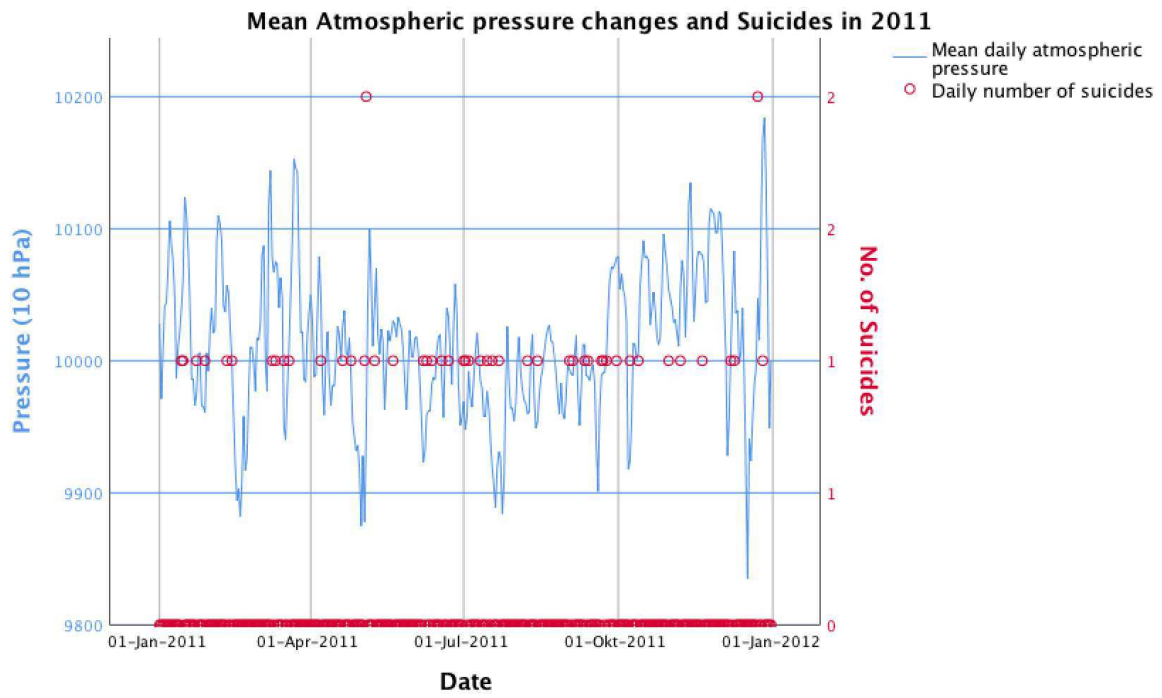


Figure 3. (Part 1/3). Mean atmospheric pressure changes and suicides



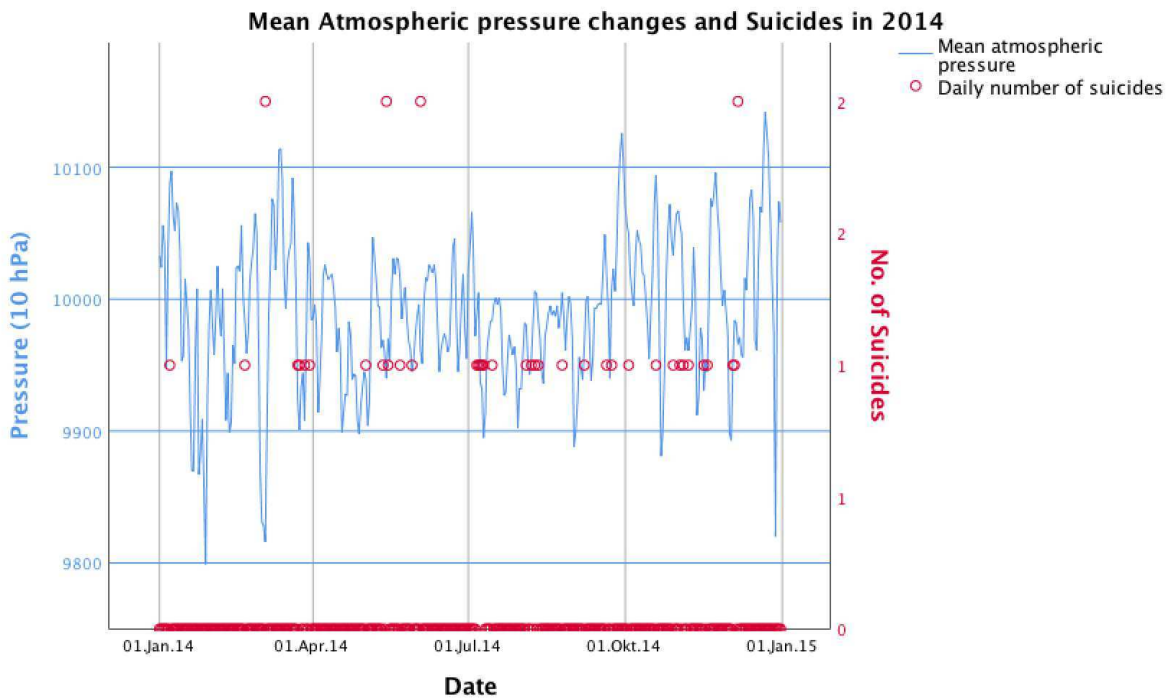
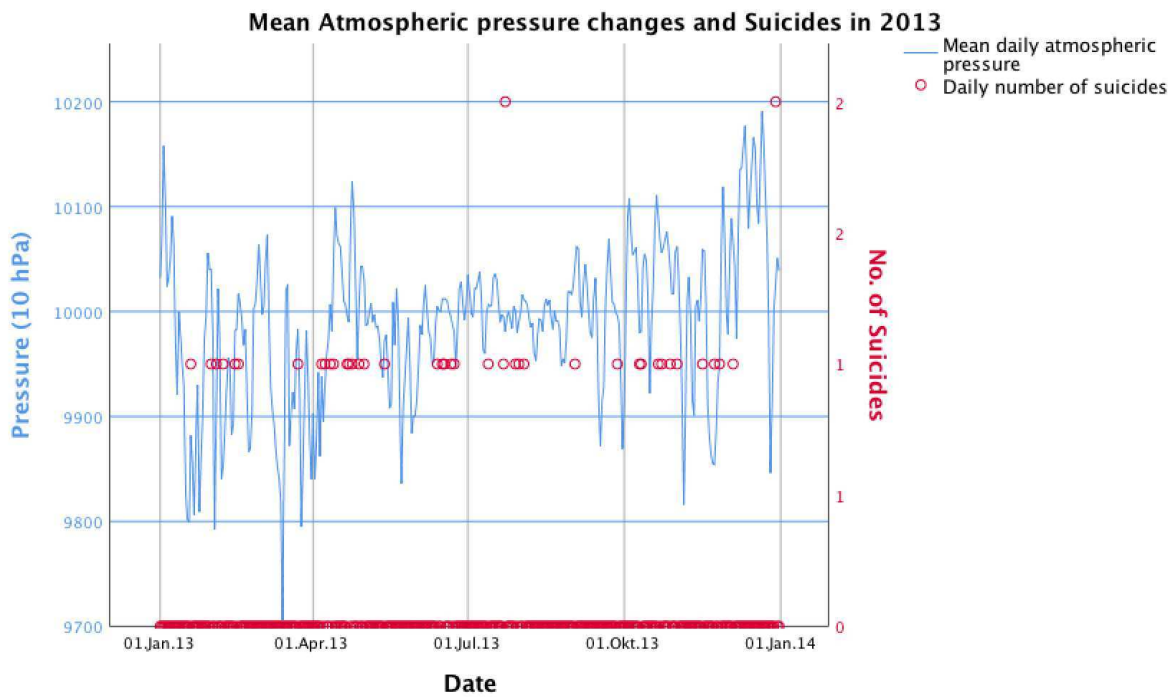


Figure 3. (Part 2/3). Mean atmospheric pressure changes and suicides

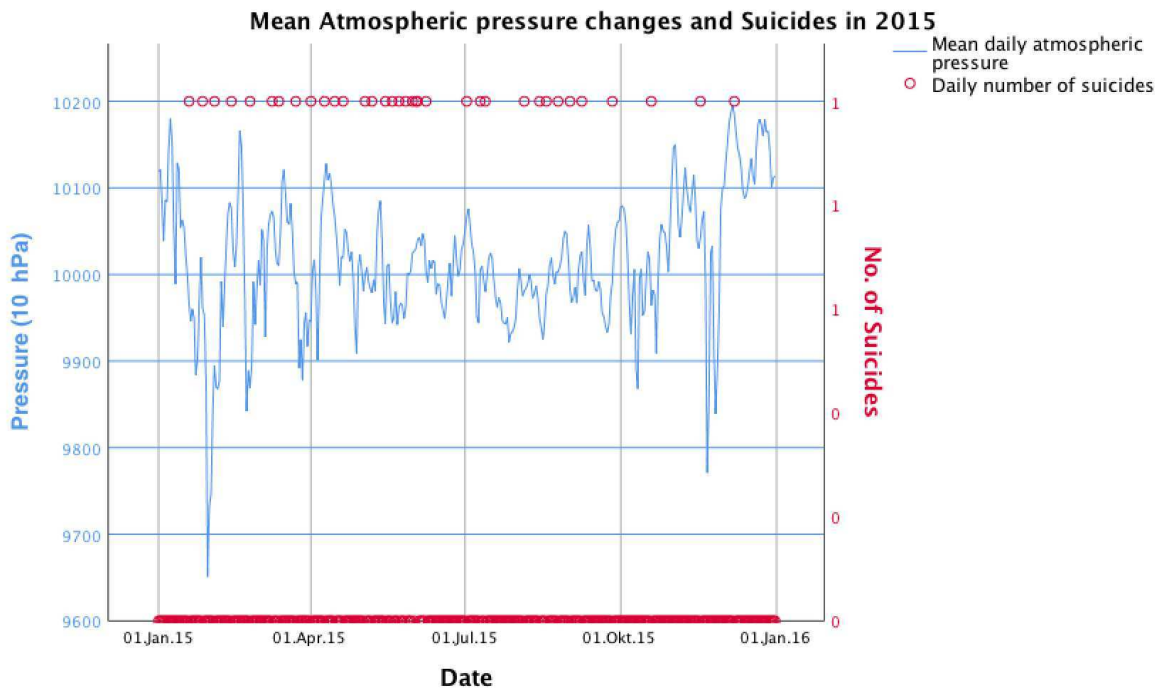


Figure 3. (Part 3/3). Mean atmospheric pressure changes and suicides

## **5. DISCUSSION**

This study examined the effect of weather factors like daily sunshine duration, daily mean temperature, barometric pressure, daily mean relative humidity, cloud coverage and specific weather events on suicide rate in the area of Split-Dalmatia county. Evaluation of the data yielded two main results, namely that mean sunshine duration on the day of the event is positively correlated with suicide and conversely, cloud coverage on the day of the suicide shows negative correlation, meaning on cloudy days, there were fewer suicides. Those results were in line with several other studies investigating the influence of weather factors on suicide rates. In addition to that, by differencing the time series, it was possible to narrow down the effect on the factor alone and to reduce the influence of seasonal variation of weather and suicide rates.

In contrast to what one would suspect, that suicide may occur more often in unpleasant and cold weather, these results reflect the newer scientific opinion supported by majority of available literature. One possibility to explain this circumstance is the hypothesis that sunshine is affecting neuro-hormonal regulation. This happens mainly by targeting the serotonin pathway and consequently, influencing mood and impulsivity as well as aggression (74-76). It is suggested that more sunshine increases motivation at first before it changes the mood (77). During bright light therapy in patients with seasonal depression, a slight increase in suicidality of patients could be proven in the first cycles of therapy (78).

As previously mentioned, suicide is strongly connected to mood disorders which are known to be characterized by dysfunctional serotonin metabolism. In seasonal affective disorders, serotonin transporters are hyper functional during depression but normalize after light-therapy or due to seasonal increase of sunlight during summer (79). The fact that there is statistically significant negative correlation between daily suicide numbers and cloud coverage can be seen as confirmation of the sunshine result and is not further discussed.

When distinguishing between male and female suicides those results were not reproducible. Despite considerable amount of data that there is a positive correlation of sunshine and suicide also in women, in some studies it is described as even stronger, this was not the case in our investigation (77,80). This may be attributable to the study size with only 65 cases of female suicide. Concerning the other factors, no statistically significant correlations could have been established.

In contrast to our result where we did not find a significant positive correlation between suicide and temperature, there is considerable amount of studies suggesting such an

influence (53,81-84). It is hypothesized that warmth acts on temperature sensitive ion channels who in turn act on specific serotonergic neurons and therefore can modulate mood and cognitive function (85). Moreover, results of studies concerning the connection of relative humidity with suicide are ambiguous. Most recent studies found a connection only in men and only on a particular time span (86). Apart from the mentioned factors, there is also evidence linking suicide with atmospheric pressure, especially in male suicides (87,88). Again, similar to sunshine and temperature, atmospheric pressure may have an influence on neuro-hormonal regulation. Different studies suggest an association of barometric changes on monoamine metabolites in cerebrospinal fluid (89-91).

It is easy to recognize a particular pattern in how weather factors may influence human behavior. All of those mechanisms affect, to some degree, neuro-hormonal pathways, at least to what is currently known. As previously stated, especially these pathways are often dysfunctional in suicide victims. So despite acknowledging that there is some possibility of an influence on suicidality, it is also important to point out the unlikelihood of a weather factors as sole trigger in a mentally and physically healthy person.

The results of southerly and northerly winds, jugo and bura, were surprising to some extent since a strong positive correlation of southerly winds was suspected due to experiences in every day coroners work as well as the cultural perception of these winds in the population of Split. Even though there were not statistically significant, the opposite was the case, since bura appears to be a risk factor rather than being protective, and jugo exerts only a very weak influence. Overall, the body of evidence concerning local weather phenomena or thunderstorms is rather weak. Vyssoki et al. investigated a catabaric wind in Austria, so called Foehn, but despite being a descending wind, it does not share many similarities with the winds we took in consideration. They did not find a significant correlation (92).

One explanation why our results were not in line with the mentioned studies may be that specific weather factors may take more time to have an effect on suicide and therefore were not detectable by this study design since the data was compared on a day-to-day basis, using mean daily weather data. So this concept is useful to identify acute stressors which can lead to suicide but rather inappropriate to look for diathetical factors. In addition to that, the generally stable climatic conditions in the Mediterranean may play a role. As described

before, the mentioned weather variables do not change exceedingly in short term in the area of Split-Dalmatia. That is why the results of the present study may differ compared to others.

But generally, it appears to be a common problem to compare studies investigating weather effects due to the variety in their methodology (64).

The present study has some limitations. First of all, the study size with 214 investigated cases can be considered small. As already mentioned, when distinguishing male and female subgroups, number of subjects in the subgroups became so small, that interpretation of these results turned out to be difficult. Secondly, the area we looked at with its specific climatic conditions may not be comparable to others in the world. On the other hand, this is also a strength of this study since the size of Split-Dalmatia-County makes the cases very comparable with each other and one can assume that the weather factors in this area affect the whole group in the same way. Another limitation lies in the analysis of the weather factors themselves. Many of them are codependent, storms often come with low pressure, when the sun shines there can't be clouds. And lastly, the underlying causes of the suicides were not taken into consideration, since this data was not accessible to us. Before mentioned external and internal causes like genetic factors, psychiatric condition or substance abuse were not known and therefore not taken into account.

Prospective investigation could aim at a number of unanswered questions. First the exact mechanism of some weather conditions influencing suicidal behavior is still unknown. Second, what does have more impact, the weather factor itself or just the change of weather? In addition to that, what amount of time does a particular weather variable need to exert its influence on suicide. Furthermore, the influence on attempted suicide. And lastly it would be helpful to include the underlying causes respectively other predispositions to suicide in order to make the data more robust.

Certainly the topic will gain importance since weather phenomena appear to become more and more violent with climate change.

But still, this requires a more robust body of evidence to confirm the correlation between distinct weather factors or phenomena with suicide to make this preventable cause of death more predictable and preventive measures can be intensified in times with specific climate factors so their effectivity increases.

## **6. CONCLUSION**

The present study, investigating the influence of weather factors on suicidality, yielded the following results.

1. Sunshine duration and cloud coverage showed statistically significant but very weak correlations with daily suicide rate. Hours of sunshine in a positive direction and conversely cloud coverage in negative.
2. Atmospheric pressure, relative humidity, mean temperature, wind direction and speed showed non-significant correlations.
3. Effect sizes are very low.
4. Results are not reproducible in the female subgroup.





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## **8. SUMMARY**

**Objective:** To investigate the relationship between climatic factors and daily numbers of completed suicide in the area of Split-Dalmatia County in the years 2011 to 2015.

**Subjects and methods:** Retrospective analysis of all suicides between 1<sup>st</sup> of January 2011 and 31<sup>st</sup> of December 2015. Weather variables of interest were sunshine duration, atmospheric pressure, temperature, relative humidity, wind direction (Bura/Jugo) and wind speed. Data was collected on the weather station Split Marjan and compared on a day-to-day basis with daily number of suicides. Timelines for each variable were created and Pearson correlation coefficients were calculated to demonstrate possible associations. Calculations were repeated distinguishing between male and female suicides. To reduce seasonality, data on weather and suicides were differenced.

**Results:** Positive weak correlation was found between sunshine duration and number of daily suicides ( $r=0.057$ ;  $P=0.015$ ) and conversely weak negative correlation between cloud coverage and number of daily suicides ( $r=-0.052$ ;  $P=0.057$ ). These associations were found in the whole sample as well as only in men. When comparing male to female suicides, these results were not reproducible in the female population.

**Conclusion:** This study confirms the hypothesis that sunshine may facilitate suicide and conversely cloud coverage can be seen as protective factor. Associations with other climatic factors may be present but due to the complexity of the interaction between weather and human behaviour and health, difficult to demonstrate.

## **9. SAŽETAK**

**Naslov:** Utjecaj vremenskih uvjeta na stopu samoubojstva u Splitu ode 2011. Do 2015. Godine.

**Cilj:** Istražiti povezanost klimatskih čimbenika i broja samoubojstava u Splitsko-dalmatinskoj županiji u razdoblju 2011.-2015. godine.

**Ispitanici i metode:** Ovo istraživanje predstavlja retrospektivnu analizu stope samoubojstava između 1. siječnja 2011. i 31. prosinca 2015. Vremenske varijable koje su se analizirale su trajanje sunca, atmosferski pritisak, temperatura, relativna vlažnost te smjer i brzina vjetra. Podaci su prikupljeni s vremenske postaje Split-Marjan i uspoređeni na dnevnoj bazi sa stopom samoubojstava. Za svaku varijablu je izračunat Pearsonov koeficijent s ciljem utvrđivanja mogućih povezanosti. Izračuni su ponavljani i s ciljem utvrđivanja razlike po spolu. Kako bi se izbjegla sezonalnost podaci su diferencirani.

**Rezultati:** Pozitivna korelacija je utvrđena između trajanja sunca i broja samoubojstava po danu ( $r=0.057$ ;  $P=0.015$ ) i posljedično negativna korelacija između oblačnog vremena i stope samoubojstava ( $r=-0.052$ ;  $P=0.057$ ). Ove povezanosti su utvrđene u cijelom uzorku, i kod mušaraca. Uspoređujući muška i ženska samoubojstva, rezultati se ne mogu primijeniti na žensku papulaciju.

**Zaključak:** Ovo istraživanje potvrđuje hipotezu da sunce može potaknuti samoubojstva i da je oblačno vrijeme zaštitni čimbenik. Povezanosti s ostalim klimatskim čimbenicima mogu biti prisutne, ali zbog kompleksnosti interakcija vremena, ljudskog ponašanja i zdravlja se otežano pokazuju.

## **10. CURRICULUM VITAE**

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