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The effects of slight atmospheric pressure fluctuations on the occurrence of emergency transport due to suicidal injuries

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ABSTRACT

The objective of this study was to test the hypothesis that a relation exists between slight atmospheric pressure fluctuations (APF) in the far infrasound frequency range and daily number of emergency transport events due to suicidal injuries (EESU). The regression models to compare groups were used to assess the relation of EESU to the mean daily amplitude of APF (APF-A) and to the ratio of APF amplitude averaged over the daytime to the APF amplitude averaged over the nighttime (Rdn). To eliminate the confounding effects of basic meteorological parameters and annual trend in EESU, the non-parametric smoothing method was used in a stepwise manner. The low APF-A (95% CI = 1.06-1.16 Pa) compared to their common middle levels and the high (95% CI = 3.18-3.64 Pa), as well the low Rdn (CI = 0.83-0.92) and very high Rdn (CI = 3.05-3.77) compared to their more closed to common regular values (CI = 1.69-1.90) turned out to be more beneficial factors promoting the decrease in the incidence of EESU. We suppose that more attention needs to be paid to the meteorotropic effects of APF on certain kinds of psychopathology resulting in suicidal behaviour, and further investigations in different geographical and climatic conditions, especially in those with more intense atmospheric perturbations, are necessary.

Keywords: Atmospheric Pressure Fluctuations; Suicidal Injuries; Emergency Events

1. INTRODUCTION

The weather effects upon human mental state and behaviour have long been discussed in literature. There are considerable numbers of evidences on the severe negative weather after-effects on people with psychical disorders resulting in suicidal behaviour. The basic meteorological parameters (ambient temperature, humidity, atmospheric pressure and wind velocity), as well the certain physical weather condition (hours of sunlight, cloud cover and precipitation) were suggested as the external triggers for development of suicidal ideation and action [1-7].

However, very little attention has been paid to possible effects of other atmospheric parameters on human behaviour. It was suggested, that slight atmospheric pressure fluctuations (APF) in the far infrasound frequency range is important meteorotropic factor influencing on mental function and behaviour [8-10]. The APF penetrate into buildings [11,12], therefore they could influence on people indoors and, as well as outdoors.

Long ago Mezernitsky P.G. [13] pointed to the high sensitivity of the central nervous system to atmospheric pressure "micropulsations". Vladymirsky B.M. [9] suggested the psychotropic effects of natural atmospheric infrasound. In line with these suggestions Green J.E. and Dunn F. [8] reported the correlation between strong naturally occurring infrasonics and selected kinds of human behaviour.

The possible effects of natural APF on human mental activity and autonomic indices, as well the symptoms of central nervous systems and vestibular disorders were confirmed by the experimental investigations with artificial pressure oscillations in the far infrasound frequency

range [10,14].

Some authors believed that the increase in anxiety levels in people with mental disorders or incidences of suicides during episodes of strong wind could be at least partly due to meteorotropic effects of APF created by wind induced turbulence of airflows [10,15].

The objective of this study was to examine whether a relation exists between natural APF and suicidal behaviour. For this the daily number of emergency transport events due to suicidal injuries (EESU) was related to mean daily integral amplitude of APF (APF-A) in the far infrasound frequency range and to the ratio of APF integral amplitude averaged over the daytime to the APF integral amplitude averaged over the nighttime (Rdn). The study was performed in Kiev locality (Ukraine) with moderate climatic condition, where calm and relatively slight windy weather is prevailing.

2. MATERIALS AND METHODS

Daily numbers of emergency transport events on suicidal injuries (EESU) for the period from 1 July 2005 to 30 June 2006 were obtained from Kyiv Station of emergency services and medicine of catastrophes. During this time the outdoor continuous measurements of atmospheric pressure have been performed with a standard microbarometer. The value of atmospheric pressure was recorded every 0.5 s. A special computer program developed by us was used to calculate average integral amplitudes of APF in the range of their periods from 3 s to 120 s over each 1 h of the day. The range of APF periods was selected allowing for the results of previous investigations of biological effects of APF in the far infrasound frequency range [10,12].

The mean daily value of APF integral amplitude (APF-A) and the ratio of APF integral amplitude averaged over the daytime (from 8:00 to 20:00 hours) to APF integral amplitude averaged over the nighttime (from 20:00 to 8:00 hours) (Rdn) were used for the analysis allowing for the results of previous investigations of biological effects of APF in the far infrasound range of their periods [12].

Three-hourly meteorological data were obtained from Kyiv Geophysical Observatory for the same year period. Mean daily temperature (T), relative humidity (RH) and atmospheric pressure (AP) were considered as potential confounding variables for the relation of EESU to APF-A.

As APF are causally related to wind induced turbulence, the possible interrelation between effects of APF-A and wind velocity (WV) was examined.

The number of a day in the course of the year (Y) was included in the model to control the effects of time-varying environmental factors on the year dynamics of EESU. This variable has associations with annual changes in length of daylight, weather parameters and social factors influencing on suicidal rates.

The polynomial approximation was used to assess visually the functional shape of yearly dynamics of EESU, as well as EESU relations with APF-A and Rdn.

The regression models to compare groups [16] were used to assess the relation of EESU to APF-A and Rdn.

If significant difference in EESU was revealed between two categories of the values of independent variable the numbers of days in first and second categories were defined by changing the boundary between them until the most significant difference in EESU was obtained.

The negative or positive effect of the one category of values of independent variable versus the other category was determined correspondingly as a percentage increase or decrease in number of EESU.

To eliminate the effects of potential confounding variables, the non-parametric smoothing method (Loess technique) was used in a stepwise manner [17].

We controlled the day of the week effects by dummy variables. All public holidays were excluded from the data. A few days of EESU and atmospheric data were lost. Hence 345 days were used for the analysis.

The number of EESU and values of atmospheric parameters were not normally distributed. Therefore, non-parametric (Mann-Whitney U-test and Spearman's rank correlation test) estimations were used. Matlab 6.5 (Curve Fitting Toolbox), Statistica 6 and MS Excel were applied for statistical analysis.

3. RESULTS

3.1. Atmospheric Data

Table 1 provides data on APF-A and Rdn values. Maximal value for hourly amplitude of APF during the year was 22.5 Pa.

We found high correlation between APF-A and WV ($r = 0.72$, $p < 0.00001$), though this correlation was significantly reduced ($r = 0.23$, $p = 0.04$, $n = 77$) in the range of low WV values (< 1.5 m/s). Dependency of the correlation coefficient on the value of WV was consistent with the non-linear character of causal relationships between APF and WV [18]. According to this character, at high WV (above 2 m/s) the APF increased rapidly with increasing WV, as the wind-induced effects dominated. At lower WV value (less than 0.5-1.5 m/s) there was only a moderate increase in the APF, as they were less dependent on the wind.

3.2. EESU Data

The total number of EESU for 345 days was 1036.

The yearly dynamics of EESU revealed significant seasonality (**Figure 1**). The significant season-specific

Table 1. Data on daily values of APF and Rdn during the year.

	95% CI	Maximum	Minimum
APF-A (Pa)	2.64-3.05	11.07	0.7
Rdn	1.43-1.62	7.2	0.21

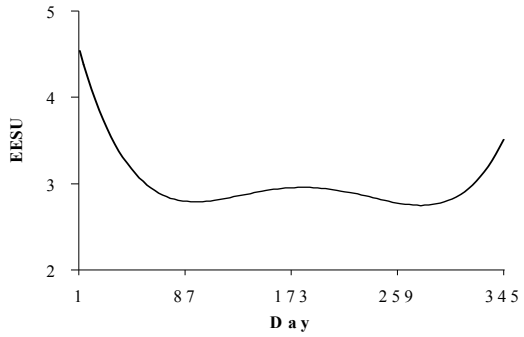

Figure 1. Polynomial model of yearly dynamics (from 1 July 2005 to 30 June 2006) of the number of EESU.

difference in the number of EESU was found between warm days (T, CI = 17.40°-19.18°) during summer-autumn season (from 1 July to 5 October 2005 and from 2 June to 30 June 2006, n = 122) and the other colder days (T, CI = 1.45°-3.75°) of the year (from 6 October 2005 to 1 June 2006, n = 223). The number of EESU proved to be greater (CI = 3.01-3.72) during warm summer-autumn period in comparison with the colder period of the year (CI = 2.60-3.06, p = 0.01).

3.3. The Relation between EESU and APF-A

The APF-A did not reveal significant relation with EESU when their raw data were considered (**Figure 2**). The functional form of the relation between EESU and APF-A was changed after adjustment for the Y and T variables. Significant difference in EESU was found only between two categories of APF-A values, which we considered as low and middle-high (**Table 2**). The number of EESU turned out to be significantly less on days with low APF-A than on days with middle-high APF-A. The category of low APF-A included about one fourth of all days of the year (n1 = 85). The other days (n2 = 260) with middle and high APF-AI compiled the second category.

Significant difference in the number of EESU between two categories of APF-A values, which was revealed after adjustment for Y and T, pointed to interfering effects of these two confounding variables on the relation between EESU and APF-A. It was mentioned above that greater numbers of EESU were observed during warm summer-autumn season compared to the other colder time of the year. Even more pronounced difference in EESU was found between two categories of T values. The number of EESU was significantly

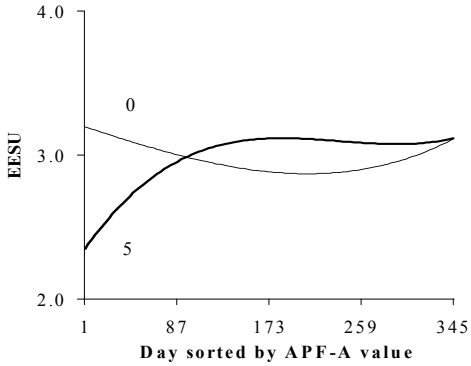

Figure 2. The number of EESU plotted against the day sorted by APF-A value in ascending order. Polynomial model: thin line (0)—raw data, thick line (5)—data adjusted for the four potential confounding variables (Y, T, AP, RH) and Rdn.

Table 2. 95% Confidence intervals for two categories of APF-A (low and middle-high) and corresponding number of EESU for data adjusted for two variables—Y and T (EESU/2) and five variables—Y, T, AP, RH and Rdn (EESU/5).

	Low APF-A 95% CI n1 = 85	Middle-high APF-A 95% CI n2 = 260	P Value
APF-A (Pa)	1.06-1.16	3.18-3.64	
EESU/2	2.34-3.03	2.90-3.31	0.046
EESU/5	2.25-2.90	2.95-3.29	0.0034

Note: p - significance of the difference in the number of EESU between two categories of APF-A values.

greater (p < 0.002) on days with high T (17.15°C (CI = 15.97-18.32), n2 = 128) compared to days with low T (2.8°C (CI = 1.66-4.03°C), n = 217). The ranges of T values on days with low and middle-high APF-A turned out to be significantly different also. The value of T was almost two times higher (13.35°C (CI = 11.23-15.46)) on days with low APF-A compared to days with middle-high APF-A (6.39°C (CI = 5.11-7.66)). Therefore, the decrease in number of EESU on days with low APF-A, which prevailed during warm season, could be interfered by simultaneous effects of the comfort warm T promoting an increase in number of EESU.

The difference in number of EESU between two categories of APF-A values remained significant after following stepwise adjustment for the AP and RH variables (p = 0.02). After additional adjustment for the Rdn the significant difference in EESU between low and middle-high APF-A became more pronounced (p = 0.0034, **Table 2**). The percentage decrease in the number of EESU on days with low APF-A versus the middle-high APF-A was –17.6% (–23.7 - –11.8).

This difference was also significant after additional adjustment for WV (after adjustment for the four confounding variables and WV p = 0.033) that suggested the

independent on WV effects of APF-A on EESU.

3.4. The Relation between EESU and Rdn

Figure 3 shows the functional shape of plots of EESU (raw data and data adjusted for the four variables and APF-A) vs the day sorted by Rdn value in ascending order. This shape suggested the three categorical model of the relation between EESU and Rdn. After adjustment for the four variables and APF-A significantly greater number of EESU proved to be at days with Rdn middle-high (n2 = 161) values comparing to days with Rdn low (n1 = 150) or very high (n3 = 34) values (**Table 3**). This classification of Rdn values was used taking into consideration the mean year magnitude of Rdn (**Table 1**). The percentage decrease in the number of EESU on days with low or very high Rdn versus the middle-high Rdn was correspondingly: –10.3% (–10.4 - –10.4) and –23.6% (–32.9 - –16.1).

The relation of EESU with Rdn remained significant after additional adjustment for WV (after adjustment for the four confounding variables and WV $p_{1,2} = 0.03$, $p_{2,3} = 0.01$).

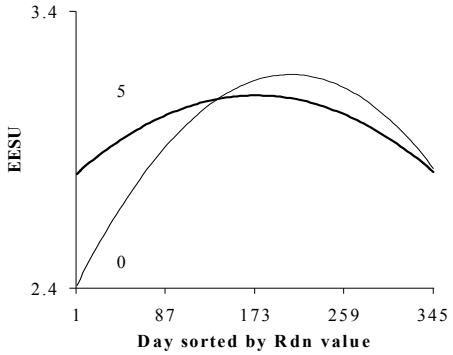

Figure 3. The number EESU plotted against the day sorted by Rdn value in ascending order. Polynomial model: thin line (0)—raw data, thick line (5)—data adjusted for the four potential confounding variables (Y, T, AP, RH) and APF-A.

Table 3. 95% Confidence intervals for three categories of Rdn (low, middle-high and very high) and corresponding number of EESU for raw data (EESU/0) and data adjusted for five variables - Y, T, AP, RH and APF-A (EESU/5).

	Low Rdn 95% CI n1 = 150	Middle-high Rdn 95% CI n2 = 161	Very high Rdn 95% CI n2 = 34
Rdn	0.83-0.92	1.69-1.80	3.05-3.77
EESU/0	2.47-3.02 $P_{1,2} = 0.02$	2.96-3.57	2.00-3.14 $P_{2,3} = 0.07$
EESU/5	2.67-3.11 $P_{1,2} < 0.05$	2.98-3.47	2.00-2.91 $P_{2,3} = 0.005$

Note: $P_{1,2}$; $P_{2,3}$ - significance of the difference in the number of EESU between days with correspondingly: low Rdn and middle-high Rdn; middle-high Rdn and very high Rdn.

4. DISCUSSIONS

4.1. The Relation between EESU and APF-A

To our knowledge, only one communication has been published on the relation between natural APF and human behaviour. Green J.E. and Dunn F. [8] found a correlation between the presences of strong infrasonic disturbances generated by natural atmospheric phenomena and automobile accidents, as well the schoolchildren behavioural demonstrations of being unwell.

We found that the number of EESU was greater at days with common middle and high APF-A compared to the days with low APF-A. These findings suggest the high sensitivity of people with suicidal psychopathology to APF levels, which is in line with the some authors' belief that weather sensitivity increases in people with psychical disorders [19-22]. Obviously the APF middles levels as well as the high ones were relevant external stimulus to provocation of suicidal intentions. Previously, the stimulating effects of artificial atmospheric pressure oscillations in the range of their natural levels on human normal purposeful behavioural activity were also revealed in the experimental study [10].

In contrast, the lack of activating influences of APF at days with their low levels seems to be the positive factor favouring to decrease in risk of suicidal actions, as well the incidence of EESU. The decrease in number of suicidal injuries at days with low APF could be also connected with increasing passiveness for the lack of APF in the environment, which was previously assumed [10]. From this point of view, the low levels of APF can particularly interfere with transition from suicidal ideation to suicidal action.

It follows from our results that the Y and T were important confounding variables for the relation between EESU and APF-A. These variables can be associated with certain slow time-varying environmental factors such as seasonal changes in weather, certain physical conditions and social aspects influencing on suicidal events. In considerable numbers of studies the daylight and sunlight duration, comfort ambient temperature, as well the warm months of the year (particularly summer and late spring) are considered to be an optimal condition for the suicide actions [3,4,7,23]. We found that simultaneous effects of these two variables and the APF-A on the number of EESU had opposite character. Due to interfering effects of Y and T the significant relation between EESU and APF-A was found only after adjustment for these two variables.

It is necessary to note that the present study demonstrates the significant effects of natural APF-A having lower values, than those in the experimental studies [10,14]. Apparently biological effectiveness of natural APF-A is depended on dose effects of their prolonged actions.

4.2. The Relation between EESU and Rdn

The previous study showed that daily dynamics of APF was characterized by pronounced regularity [12]. According to this regularity the mean hourly amplitude of APF increases from night to day followed by a decrease from day to night. Therefore, the possible association of daily dynamics of APF with circadian rhythms of human psychical activity could be suggested. From standpoint of behavioural continuum from sleeping to high level of vigilance the regular daily dynamics of APF could be considered as favourable factor enabling an organism to adopt to the needs of higher activity levels while awake.

We found that the number of EESU was significantly decreased at days with low (CI = 0.83-0.92) and very high (CI = 3.05-3.77) Rdn compared with middle-high Rdn (CI = 1.69-1.90) closed to mean year values of Rdn (CI = 1.43-1.62). These results indicated that the number of EESU was greater at days when the ratio of diurnal APF values to their preceding nocturnal values closed to common mean values. When nocturnal APF were higher or much less, than their diurnal values, the number of EESU was decreased. Therefore, it could be suggested that effectiveness of diurnal levels of APF in relation to EESU was depended on the foregoing nocturnal levels.

As to the activating effects of APF the decrease in their diurnal levels in comparison with the nocturnal levels indicated the decrease in effectiveness of APF as external provoking stimulus for the suicidal actions and as a consequence the decrease in the number of EESU during the daytime. The decrease in the number of EESU at days when diurnal APF were highest in comparison with the nocturnal ones could be due to "paradoxical" or antagonistic reaction with opposite character. According to the opinion of Wein A.M. *et al.* [24], such character of reaction could be evoked by irritant when the initial level of activation was abruptly altered.

4.3. The Additional Findings and Possible Implication of the Results

The previous study showed interrelated effects of high APF and WV on the number of emergency transport events due to circulatory system diseases [12]. Possible reason for the independent on WV significant decrease in EESU on days with low APF-A revealed in this study could be the non-linear relation between these two atmospheric variables [18]. According to this non-linearity, the causal relation between APF and WV is well pronounced only during strong wind, as the low WV is insufficient contributor to the APF generation. Apparently, due to the weak association of APF with low WV the relation between EESU and APF-A remained significant after adjustment for the WV.

The additional findings obtained in this study did not support also the conception of a spring peak of suicide incidence [23-25]. According to our data the number of EESU (without the reference to the sex difference) was higher during warmer time of the year in Kyiv. This time was summer and early autumn. Though, Parker G. and Walter S. [26] reported an early summer peak for both genders and early autumn peak in women.

As the future implication of this study results we suggest that the meteorological forecast of APF levels would be helpful for hospital emergency services in order to be able to prepare for potential increases in workload due to increase in traumatic accidents. The evidence, received in this study may be useful for the behavioural self-control in individuals with propensity toward suicidal ideation, as well for the relevant medical professionals.

5. CONCLUSIONS

The results of this study corroborate the suggestion that mean daily amplitudes of APF and ratio of diurnal levels of APF to their nocturnal levels are related to the risk for injuries due to psychopathological suicidal behaviour.

In this preliminary study we only found threshold effects of APF. The essential limitation of our study was the moderate climatic conditions of Kyiv locality with still or slightly windy weather prevailing. Perhaps, the functional shapes of the relation of EESU with APF are more complex than those revealed in the present study. To clear up this question it will be necessary to extend the observation over a longer period and different geographical and climatic areas, especially those where strong atmospheric pressure perturbation are frequent. Because there may be further uncontrolled factors our findings require additional corroboration.

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