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Influence of meteorological conditions on the use of coercive interventions

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Abstract— Aggressive behavior in psychiatric care is a serious problem. The causes of aggression may be ambiguous, including behaviors gender, age, or atmosphere on the ward. Other risk factors, usually not mentioned, include meteorological conditions, such as air temperature and humidity, pressure or wind. The available literature suggests a link between meteorological conditions and the use of coercive interventions in psychiatric care. In this study, we examined meteorological conditions that correlated with an increased number of cases of aggressive behavior leading to coercive interventions. The relationships between the studied variables were determined using linear correlation tests and cluster analysis. The study draws on coercive intervention records from The Józef Babiński Psychiatric Hospital in Krakow, spanning 27 months. The hospital's seventeen in-patient treatment wards, six day-care centers, nine community treatment teams, and six outpatient clinics have a capacity of 790 patients. Among patients who were susceptible to weather changes, specific weather types were identified as being related to more cases of aggressive behavior.

Key-words: meteorological conditions, physical coercion, aggressive behavior, psychiatric patients

1. Introduction

Aggressive patient behavior presents a serious problem for medical staff. Some negative consequences may be identified, including healthcare professionals' reluctance to work, professional burn-out, or compromised healthcare quality (*Chambers et al., 2015*)

The risk factors of aggression and of the exacerbation of symptoms of mental disease also include weather conditions, i.e., air temperature and humidity, pressure, wind (especially foehn wind), sunshine duration, and storms (*Almendra et al., 2019; Belleville et al., 2013; Dominiak et al., 2015; Manning and Clayton, 2018; McWilliams, et al., 2014; Nastos et al., 2017; Santiago, et al., 2005; Shiloh et al., 2005*).

The variability of meteorological conditions over the course of the year and the occurrence of seasonal weather events has a strong impact on the human body. Such adverse meteorological conditions exacerbate disease symptoms and may increase the frequency of aggressive behavior among susceptible individuals. Strong atmospheric stimuli have an especially strong impact on the human nervous system, especially in highly excitable people (*Vida et al., 2012*). Researchers in Netherlands, Germany, Belgium, England, and Poland have found that patients suffering from depression, schizophrenia, as well as alcohol and drug addiction, are the most susceptible to weather conditions and their abrupt changes. The researchers have also confirmed the periodic nature of nervous system conditions (*Shiue, et al., 2016*).

There are researchers, who suggest an increased number of aggressive incidents between January and April, in the summer season, and in autumn (*Peluola, et al., 2013; Weizmann-Henelius, 2000*). Finnish research has found that fewer coercive interventions were required in January (*Kuivalainen et al., 2017*). Coercion was more often used in psychiatric wards in Finland between June and November, and during the summer in Norway (*Reitan, et al., 2018*).

Atmospheric factors have an impact not only on the number of aggressive incidents, but also on self-destructive behavior and the use of coercion. Research conducted in many countries suggests that patients suffering from mental diseases are the most sensitive to weather (*McWilliams et al., 2014*). This relationship has also been noted in regard to self-aggressive behavior (*Yackerson, et al., 2014*).

The aim of the paper was to determine meteorological conditions prevailing during periods with more cases of aggressive behavior leading to coercive interventions in patients treated at a psychiatric hospital in Krakow (Poland, Central Europe).

2. Material and methods

The study was carried out at the largest psychiatric care facility in the Lesser Poland Region – the Józef Babiński Psychiatric Hospital in Krakow. It's

seventeen inpatient treatment wards, six day-care centers, nine community treatment teams, and six outpatient outpatient clinics can receive up to 790 patients. Annually, the hospital provides more than 8500 inpatient treatment services, and 85,000 people receive care out-patients as outpatients.

To determine the impact of weather conditions on the frequency of coercive interventions, “coercion sheets” filled out between January 1, 2015 and March 31, 2017 were analyzed. The paper has been approved by the Ethics Committee. During the studied period, the principles of recording coercive interventions were modified, enabling a more precise description of individual cases. A period of 27 months allowed the authors to take into account both relatively warm winter seasons, atypical considering the climatic conditions of Central Europe, as well as normal ones with characteristic frost waves.

When analyzing the data, the authors considered the date and time when the coercive intervention started, suggesting that the aggressive behavior occurred immediately beforehand. The researchers paid special attention to days, where a large number ($N > 8$) of coercive interventions occurred. The adopted threshold resulted from the distribution of frequencies and values exceeding the mean daily number of events within the analyzed period.

The weather conditions prevailing in Krakow on the analyzed days were determined on the basis of meteorological measurements and observations taken at the Climatology Station of the Jagiellonian University. The daily values of air temperature: daily average, maximum, and minimum ($^{\circ}\text{C}$), air pressure (hPa), relative humidity (%), average wind speed (m/s), cloud cover (%), and sunshine duration (hours) were used in the analysis.

In order to determine the cumulative impact of weather on the number of coercive interventions, the researchers used the Synoptic Situations Calendar prepared by *Niedźwiedź* (2020), which can be used to identify types of circulation over southern Poland (the presence of anticyclones or cyclones), the direction of advection and type of air mass, as well as the presence of weather fronts (*Table 1*). Conditional probability of the occurrence of days with an increased number of coercive interventions ($N > 8$) was calculated in particular synoptic situations. Meteorotropic situations include, above all, cyclonic situations (lows), passage of weather fronts (especially cold ones), and advection of air masses with contrasting physical characteristics, as well as stormy weather (unstable state of the atmosphere) and foehn situations (foehn is a dry and warm wind blowing from the mountains). The above synoptic situations involve rapid changes in meteorological conditions which have a strong stimulating effect on the human body.

Table 1. Synoptic situations, air masses, and atmospheric fronts
(according to the catalogue prepared by Niedźwiedź, 2020)

Symbol	Name
Circulation types	
E+SEa	Anticyclonic situations with an advection of air masses from east and south-east
Ca+Ka	Central anticyclonic situation, anticyclonic wedge
Cc+Bc	Central cyclonic situation, trough of low pressure
S+SWc	Cyclonic situations with an advection of air masses from south and southwest
S+SWa	Anticyclonic situations with an advection of air masses from south and southwest
E+SEc	Cyclonic situations with an advection of air masses from east and southeast
W+NWc	Cyclonic situations with an advection of air masses from west and northwest
W+NWa	Anticyclonic situations with an advection of air masses from west and northwest
N+NEa	Anticyclonic situations with an advection of air masses from north and northeast
N+NEc	Cyclonic situations with an advection of air masses from north and northeast
x	Unclassified situation
Air masses	
PPk	Polar continental
PPms	Polar maritime old (transformed)
PPmc	Polar maritime warm
PPm	Polar maritime (fresh)
rmp	Various air masses in day
PZ	Tropical air masses
PA	Arctic air masses
Atmospheric fronts	
-	Day without front
z	Cold front
c	Warm front
st	Stationary front
r	Several various fronts in day
o	Occluded front (occlusion)

In order to explore the relationship between the weather conditions on days with a larger number of coercive interventions, the differences between the average value of individual meteorological elements for each day in the years 1981–2010 and the value of a given day with $N > 8$ (daily anomaly) were calculated (N is the number of coercive interventions). Spearman's rank linear correlation and multiple correlation coefficients were used. The statistical significance was determined as $p < 0.05$. A cluster analysis was also performed to explore the relationship between meteorological conditions and the number of cases of aggressive behavior which resulted in coercive interventions. This statistical method is especially useful in the analysis of multiple variables, just as in the case of this study. Thus, each day with more than eight coercive interventions had

certain weather conditions characterized by a set of individual meteorological elements. These can be grouped into clusters if treated as multi-property objects. Objects which belong to the same group (cluster) are the most similar to one another (in our case, they had similar weather conditions), while those which belong to different groups differ most from each other. This method also allows for the identification of dominant elements, which have the greatest influence on, and which distinguish, a particular group.

A hierarchical (agglomeration) method of cluster analysis and tree diagram (Word's method) was used in the first step. Four clusters were selected, which very well represented the weather conditions in the seasons. The method of k-average allowed to add each day into a separate group. Grouping was carried out for all meteorological elements and their deviations from the 30-year average (1981–2010).

3. Results

There were 329 days with a large number of cases of aggressive behavior leading to coercive intervention ($N > 8$) in the period from January 1, 2015 to March 31, 2017. Such days accounted for 40.1% of all analyzed days in analyzed period, out of which 21.3% were days with 9 or 10 coercive situations, 16.9% with 11–15 and 1.8% with more than 15 coercive situations. The greatest number of coercive interventions on a single day, namely 19, occurred on July 10, 2016. Their distribution in the analyzed months is presented in *Fig. 1*. On average, there were 13 days per month, with the largest number occurring in April 2016 (20 days) and the smallest in April 2015 (2 days). No clear difference in the course of such days during the year was identified. On average, there was only one further similar day in autumn and 2 in spring, fewer than the average for the entire period (*Fig. 1*).

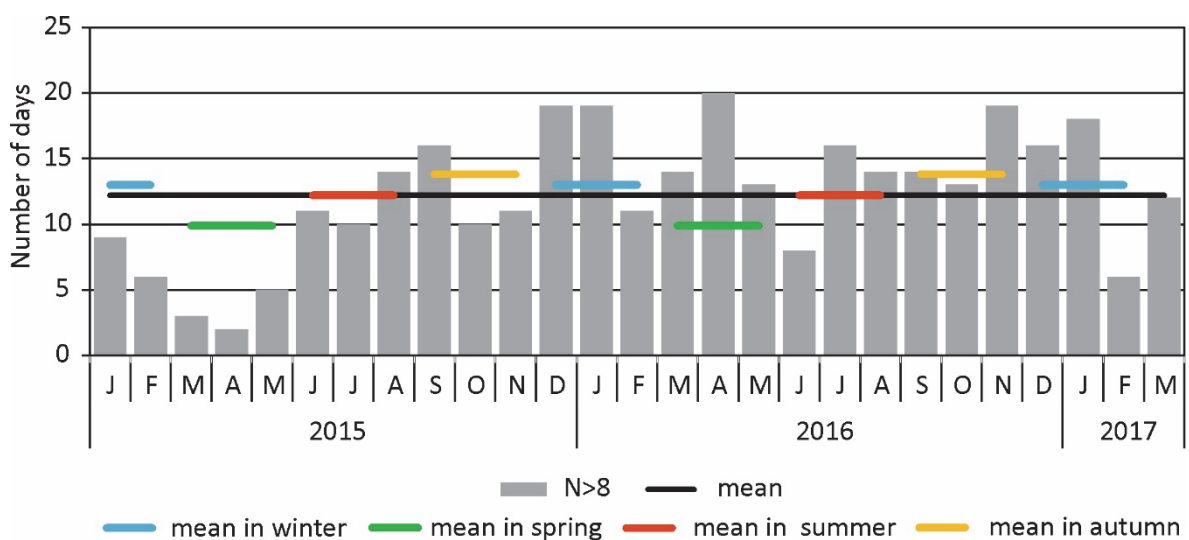


Fig. 1. Number of days on which physical coercion was used towards at least 9 hospital patients ($N > 8$) and mean number of this days in particular seasons in the period from January 1, 2015 to March 31, 2017.

Few such studies, especially those conducted in the context of diseases of the nervous system, investigate the combined impact of a number of elements based on synoptic situations prevailing over a given area (pressure system with advection directions of specific air masses and the presence of weather fronts). Information about synoptic situations on a given day and those expected over the next few days is widely available since it serves as a basis of weather forecasts.

For southern Poland, *Niedźwiedź* (2020; *Table 1*) has prepared a calendar of synoptic situations, using which the synoptic situation on a given day was determined in the present study. A slightly higher conditional probability of the occurrence of days with $N > 8$ was found for cyclonic situations, i.e., those with low atmospheric pressure (43.1%), than for anticyclonic situations (high atmospheric pressure; *Fig. 2a*). Probability of over 50% occurred with the following types of circulation: Nc (cyclonic situations with advection of air masses from the west; 64.3%), NWc (cyclonic situations with advection of air masses from the northwest; 61.8%) and NWa (anticyclonic situations with advection of air masses from the northwest; 51.7%). Therefore, with these three types of circulation, a rise in the frequency of days with a high number of coercive situations can be expected.

In biometeorological analyses, in addition to conditions prevailing on a given day, rapid changes over a short spell and/or from day to day, are also important. Therefore, the next step involved analyzing the types of circulation on a day with $N > 8$ and on the preceding day. It was found that the conditional probability of coercive interventions was over 70% when the synoptic situation over southern Poland changed from one day to another from a cyclonic center to a cyclonic trough (Ca-Bc) or from a cyclonic situation with advection of air masses from the northwest to an anticyclonic trough with advection from the west (NWc-Wa). A high number of $N > 8$ was also observed at times when the direction of air masses changed during cyclonic and anticyclonic situations. This included changes of advection from the west to the southwest (Wa-SWa), the east to the southeast (Ec-Sec), the northwest to the west (NWc-Wc), and from the east to an advectionless situation (Ea-Ka). The changes in the types of circulation thus distinguished occurred at least three times during the study period.

A similar analysis of the correlation between $N > 8$ and the accompanying types of circulation was conducted for air masses and weather fronts moving over Krakow. Even though the results do not demonstrate clearly which air masses predominated on the days with $N > 8$, since the conditional probability ranged from 35.9% for old maritime polar air masses (PPms) to 48.7% for various air masses (rmp) (*Fig. 2b*), it must be emphasized that the passage of various air masses over a given area during the day is indicative of rapid weather changes, and such meteorological conditions are strongly stimulating ones. In addition, Arctic air masses (PA), which form the type of air mass accompanying days with $N > 8$, which ranked third in terms of conditional probability, are rather rare in Poland.

In the period under analysis, their frequency was at a level of 7%, which indicates a fairly strong correlation with coercive measures.

As regards fronts, the conditional probability indicates that days with $N > 8$ could be correlated with the passage of a cold front (z; 46.0%) or several fronts on one day (rf; 45.6%) (Fig. 2c). These two cases are associated with dynamic change in the weather, which has an irritating effect on humans.

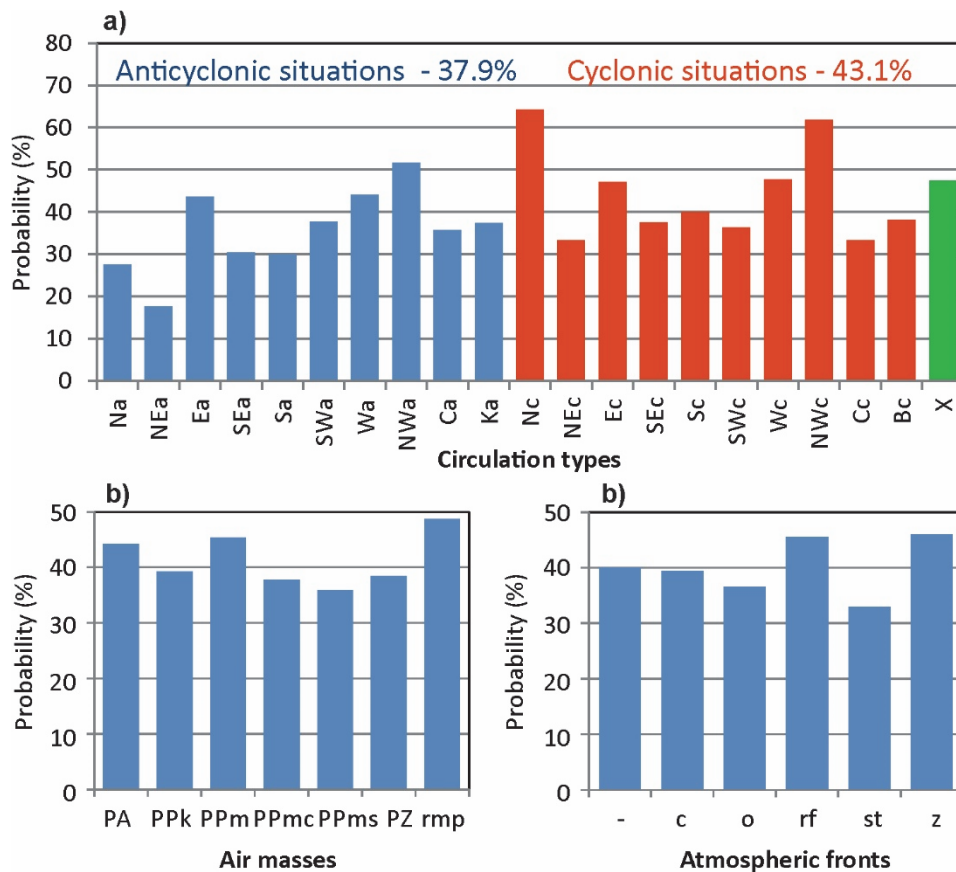


Fig. 2. Conditional probability of the occurrence of days with an increased number of coercive interventions ($N > 8$) and associated circulation types (a), air masses (b) and atmospheric fronts (c) in the period from January 1, 2015 to March 31, 2017 (explanation of circulation types is presented in Table 1).

In order to explore the relationship between the weather conditions on days with a larger number of coercive interventions, the differences between the average value of individual meteorological elements for each day in the years 1981–2010 and the value of a given day with $N > 8$ (daily anomaly) were a given meteorological element calculated. For this, the coefficients of the correlation

between the above mentioned differences for the individual meteorological elements were calculated first. The only statistically significant relationships ($p < 0.05$) were: a positive anomaly for the mean and maximum air temperatures (0.113–0.116), and a negative one (-0.116; $p < 0.05$) for the atmospheric pressure, i.e., the lower the pressure values, the larger the number of cases of aggressive behavior leading to coercive interventions. Also, no relationship was found between coercion interventions and day-to-day changes in pressure.

Next, a cluster analysis was used to analyze the identified groups of days and their weather conditions. The performed tests allowed the authors to conclude that four clusters should be identified. On this basis, the weather type, which favored a larger number of coercive interventions in particular months and groups, has been determined to identify differences against the backdrop of the long-term daily mean (1981–2020) have been determined.

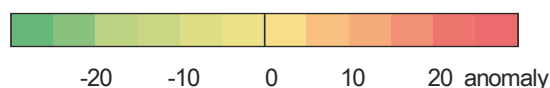
3.1. First group of days

The first and most numerous cluster (33.7% of all cases) included days occurring from October to May (in the cool part of the year) (*Table 2*). Air temperature was the factor which had the greatest influence on the occurrence of a large number of coercive interventions. In winter (between December and February), these were very atypical days for this season of the year, with a relatively high air temperature ($T_{\max} > 10\text{ }^{\circ}\text{C}$). The mean values of temperature anomalies were 5.6–8.4 $^{\circ}\text{C}$ (*Table 2*). These days were also marked by lower pressure and longer cloudiness in January and February (altered by 5.5–7.7 hPa and 1.7–5.0% from the norm). In December, pressure was above the mean long-term value (by 6.4 hPa). The relative humidity was slightly below the average in three winter months (by 1.7–5.0%), while the wind speed was slightly higher (*Table 2*). The sunshine duration did not differ from the norm.

In spring (from March to May), the temperature on the days in this group was near the average ($\pm 2\text{ }^{\circ}\text{C}$), with the exception of May, when they were on average 2.6–8.2 $^{\circ}\text{C}$ colder (*Table 2*). In March, these were days with less air pressure and in May with less humidity, but in both of these months, the cloud cover was greater and the sunshine duration shorter than the average. Days which were included in the first group but which occurred in October stood out more cloudiness, while those in November were characterised by less cloudiness (differing -12% from the norm), but were also the most sunny (the average cloud cover was around 60%).

Table 2. Mean monthly values of selected meteorological elements in the first cluster of days with an increased number of cases of aggressive behavior leading to coercive interventions in a psychiatric hospital in Krakow between January 1, 2015 and March 31, 2017

Elements	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly values												
Tmax (°C)	10.5	11.2	10.3	13.8	13.6	-	-	-	-	11.0	11.4	9.6
Tmin (°C)	2.0	2.5	1.8	4.4	7.1	-	-	-	-	4.5	2.5	3.8
Tmean (°C)	5.5	5.8	5.6	8.7	10.1	-	-	-	-	7.1	6.0	6.4
Pressure (hPa)	983.6	984.2	985.9	987.0	986.6	-	-	-	-	993.2	991.6	996.7
Humidity (%)	77.1	76.7	73.7	67.2	67.0	-	-	-	-	82.0	85.6	79.8
Wind speed (m/s)	2.7	2.1	2.3	1.9	2.3	-	-	-	-	2.3	1.3	3.0
Cloudiness (%)	73.9	77.3	76.7	65.8	75.0	-	-	-	-	77.0	60.3	75.7
SD (hours)	1.4	2.5	2.7	6.0	4.3	-	-	-	-	2.8	3.3	1.4
Mean monthly values of daily differences from 1981-2010 (anomalies)												
Tmax (°C)	8.4	7.4	1.9	-2.5	-8.2	-	-	-	-	-3.6	3.8	6.9
Tmin (°C)	6.1	5.6	2.0	-0.9	-2.6	-	-	-	-	-0.9	1.5	6.5
Tmean (°C)	6.8	5.9	2.0	-1.7	-5.2	-	-	-	-	-2.0	2.2	6.6
Pressure (hPa)	-7.7	-5.5	-2.2	0.3	-0.9	-	-	-	-	2.4	2.9	6.4
Humidity (%)	-5.0	-1.7	-0.1	0.6	-3.1	-	-	-	-	-0.2	1.5	-4.7
Wind speed (m/s)	1.0	0.3	0.3	0.2	1.0	-	-	-	-	1.0	-0.3	1.4
Cloudiness (%)	2.7	7.2	10.7	5.8	16.5	-	-	-	-	14.9	-12.8	-0.1
SD (hours)	-0.2	0.0	-0.4	0.4	-2.6	-	-	-	-	-0.6	1.6	0.3



3.2. Second group of days

In the second group, (21.9% of all analyzed days), there were those which occurred in the ten months from February to November (Table 3). Air temperature, humidity, and cloud cover were the most significant differentiating factors in this group. In summer (from June to August), an increased number of coercive interventions was accompanied by weather which was relatively cool considering the season of the year (Tmean of 16 °C and Tmax of 21 °C; anomaly from -1.4 °C to -4.1 °C), overcast (cloud cover >75% and 12–21% above normal, sunshine duration of less than 4 hours per day; anomaly from -1.4 to -3.2 hours), and with high air humidity (>75%; 2.3–4.0% above normal). In the remaining months, these were days with (Table 3):

- a higher air temperature (in February with a Tmax above 16 °C on average; anomaly from 4.4 °C to 12.1 °C),
- most frequently, almost normal atmospheric pressure (980–990 hPa), but in February with low anomaly (-12.9 hPa by mean),
- low humidity in February, March, and November (with anomaly below -6.1%) and higher humidity in the remaining months (>72%),
- most frequently, more cloudiness and somewhat shorter sunshine duration.

Table 3. Mean monthly values of selected meteorological elements in the second cluster of days with an increased number of cases of aggressive behavior leading to coercive interventions in a psychiatric hospital in Krakow between January 1, 2015 and March 31, 2017.

Elements	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly values												
Tmax (°C)	-	16.1	17.6	20.1	20.6	20.7	21.4	21.4	19.5	18.9	16.4	-
Tmin (°C)	-	6.7	7.5	8.1	10.0	12.0	15.1	13.8	11.8	9.1	9.8	-
Tmean (°C)	-	11.9	11.9	12.9	14.8	16.0	17.9	16.8	14.9	13.1	12.4	-
Pressure (hPa)	-	976.9	990.8	982.3	986.0	985.5	987.5	990.0	989.3	989.4	990.3	-
Humidity (%)	-	64.0	62.7	72.5	75.2	74.8	76.3	77.6	78.7	87.0	77.8	-
Wind speed (m/s)	-	2.3	1.8	1.5	1.7	1.6	2.2	1.7	2.0	0.7	3.1	-
Cloudiness (%)	-	66.7	72.2	71.9	67.0	75.9	79.9	75.8	79.2	68.8	59.2	-
SD (hours)	-	7.7	5.5	4.7	5.9	5.0	4.0	3.3	2.8	3.1	3.5	-
Mean monthly values of daily differences from 1981-2010 (anomalies)												
Tmax (°C)	-	12.1	7.7	6.3	0.1	-2.4	-4.1	-4.1	-0.3	4.1	8.9	-
Tmin (°C)	-	10.2	6.7	4.4	0.8	-0.5	0.7	-0.3	2.0	3.3	8.7	-
Tmean (°C)	-	12.0	7.1	4.6	0.4	-1.4	-1.4	-2.1	1.0	3.8	8.5	-
Pressure (hPa)	-	-12.9	3.0	-3.4	-1.7	-1.6	0.0	1.9	-0.5	-1.4	1.1	-
Humidity (%)	-	-12.2	-10.7	3.9	5.5	3.2	4.0	3.8	-1.5	3.6	-6.1	-
Wind speed (m/s)	-	0.6	0.0	-0.3	0.1	0.0	0.7	0.5	0.6	-0.5	1.5	-
Cloudiness (%)	-	-3.9	9.0	6.5	7.7	12.7	21.3	19.8	19.6	9.8	-15.2	-
SD (hours)	-	4.8	1.9	0.2	-0.8	-1.4	-3.0	-3.2	-1.7	-0.3	1.8	-

-20 -10 0 10 20 anomaly

3.3. Third group of days

The third group consisted of days which occurred in the cool half of the year, from November to March (Table 4). They included 24.9% of all cases. An increased number of coercive interventions was accompanied by cool weather with a $T_{max} < 4$ °C and a $T_{min} < 0$ °C, with a slightly higher atmospheric pressure (990–1000 hPa) and smaller cloud cover (<70%), with the exception of February (74%; anomaly +3.7%).

Table 4. Mean monthly values of selected meteorological elements in the third cluster of days with an increased number of cases of aggressive behavior leading to coercive interventions in a psychiatric hospital in Krakow between January 1, 2015 and March 31, 2017

Elements	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly values												
Tmax (°C)	0.9	3.1	8.3	-	-	-	-	-	-	-	3.9	3.9
Tmin (°C)	-5.6	-3.0	-0.8	-	-	-	-	-	-	-	-2.1	-2.0
Tmean (°C)	-2.7	-0.4	3.2	-	-	-	-	-	-	-	0.6	0.8
Pressure (hPa)	988.9	991.1	990.3	-	-	-	-	-	-	-	991.8	1000.1
Humidity (%)	81.4	80.3	63.8	-	-	-	-	-	-	-	82.7	82.7
Wind speed (m/s)	1.8	1.8	1.6	-	-	-	-	-	-	-	1.7	2.1
Cloudiness (%)	67.1	74.0	55.6	-	-	-	-	-	-	-	75.8	70.6
SD (hours)	2.2	2.2	6.7	-	-	-	-	-	-	-	2.1	1.9
Mean monthly values of daily differences from 1981-2010 (anomalies)												
Tmax (°C)	-1.0	-0.7	-0.5	-	-	-	-	-	-	-	-2.2	1.0
Tmin (°C)	-1.6	0.2	-0.9	-	-	-	-	-	-	-	-2.4	0.5
Tmean (°C)	-1.4	-0.3	-0.6	-	-	-	-	-	-	-	-2.3	0.8
Pressure (hPa)	-1.4	2.0	3.2	-	-	-	-	-	-	-	3.6	10.4
Humidity (%)	-0.1	0.7	-9.3	-	-	-	-	-	-	-	-3.4	-1.8
Wind speed (m/s)	0.0	0.0	-0.4	-	-	-	-	-	-	-	0.3	0.4
Cloudiness (%)	-5.3	3.7	-12.0	-	-	-	-	-	-	-	-0.1	-4.8
SD (hours)	0.7	0.1	3.6	-	-	-	-	-	-	-	0.9	0.7



3.4. Fourth group of days

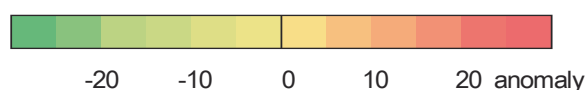
The last group was that of days occurring from May to September (*Table 5*). There were 64 of them, i.e., 19.5% of all cases. The increased number of coercive interventions was then related to weather which was (*Table 5*):

- hot ($T_{max} > 25$ °C), with anomaly of maximum air temperature from 2.4 °C to 7.1 °C,
- with low air humidity (anomaly from -5.9% in September to -13.8% in May),
- very little cloud cover (<42%; anomaly <-18.2%) and long sunshine duration (>9 hours; anomaly >3.8 hours).

The other meteorological elements did not have a major impact on the identification of this cluster.

Table 5. Mean monthly values of selected meteorological elements in the fourth cluster of days with an increased number of cases of aggressive behavior leading to coercive interventions in a psychiatric hospital in Krakow between January 1, 2015 and March 31, 2017

Elements	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly values												
Tmax (°C)	-	-	-	-	22.8	28.2	28.3	27.9	27.5	-	-	-
Tmin (°C)	-	-	-	-	9.7	14.2	15.6	15.2	13.6	-	-	-
Tmean (°C)	-	-	-	-	16.1	21.1	21.6	20.7	19.2	-	-	-
Pressure (hPa)	-	-	-	-	984.5	988.3	989.1	992.6	990.9	-	-	-
Humidity (%)	-	-	-	-	57.0	61.4	60.1	65.7	73.2	-	-	-
Wind speed (m/s)	-	-	-	-	1.7	1.8	2.0	1.7	1.3	-	-	-
Cloudiness (%)	-	-	-	-	41.7	42.9	38.5	29.9	21.7	-	-	-
SD (hours)	-	-	-	-	12.2	11.8	11.1	10.4	9.3	-	-	-
Mean monthly values of daily differences from 1981–2010 (anomalies)												
Tmax (°C)	-	-	-	-	2,4	5,3	3,1	3,3	7,1	-	-	-
Tmin (°C)	-	-	-	-	0.5	2.0	1.5	1.6	3.3	-	-	-
Tmean (°C)	-	-	-	-	1.7	4.0	2.5	2.4	4.8	-	-	-
Pressure (hPa)	-	-	-	-	-1.8	0.7	1.3	4.7	2.1	-	-	-
Humidity (%)	-	-	-	-	-13.8	-9.8	-11.3	-9.0	-5.9	-	-	-
Wind speed (m/s)	-	-	-	-	0.0	0.1	0.4	0.4	-0.1	-	-	-
Cloudiness (%)	-	-	-	-	-28.6	-18.2	-18.6	-25.9	-37.7	-	-	-
SD (hours)	-	-	-	-	6.9	5.1	3.8	4.0	4.5	-	-	-



4. Discussion and conclusions

The aim of this study was to determine the weather conditions in days with a higher level of coercion measures in a psychiatric hospital. Studies on the impact of weather conditions on patients' aggressive behaviors are rarely undertaken in research (*Brandl et al.*, 2018). Detailed studies on the influence of the weather on aggressive behaviors and the use of coercive measures have not been often conducted. The relationship between meteorological factors and the intensity of mental health problems has been confirmed by the research of *Settinieri et al.*, (2016). According to *Settinieri*, the most abrupt weather change in spring and fall cause psychopathological emergencies.

Human behavior is the result of many factors. Some of them, like weather, may additionally burden the psychiatric patients. These include a drop in atmospheric pressure (*Schory et al.*, 2003). The research results suggest, that in some months of the year, an increase in the frequency of aggressive behavior leading to coercive interventions among the patients could be related to meteorological conditions. An increase in the frequency of the analyzed events co-occurred with low atmospheric pressure. *Schory et al.* also noted the impact of low atmospheric pressure on an increased number of psychiatric emergencies and cases of violent behavior (*Schory et al.*, 2003). Low atmospheric pressure may be a risk factor for aggressive behavior, and may be related with the number of coercive measures.

The research also showed the existence of weather patterns related to the number of coerces used. This study found that with lower pressure values, the incidence of aggressive behavior in patients leading to the use of coercive measures increases. For temperature (positive correlation) and relative humidity (negative correlation), there was a poor, but statistically insignificant correlation. Perhaps this should be attributed to the fairly short series of data. By contrast, no relationship was found between intraday and day-to-day changes in pressure and the values of the other individually considered meteorological elements, and there were likewise no seasonal variations in coercion.

A synergic impact of weather can be analyzed, inter alia, on the basis of the synoptic situation prevailing on a given day and in a given area. Information about synoptic situations is communicated by every weather forecast and is available on weather websites. An analysis of medical data with the use of a calendar of circulation types leads to the conclusion that an increase in the frequency of coercive interventions was accompanied by:

- low-pressure systems, and in particular by three types of circulation: cyclonic situations with an advection of air masses from north (Nc) and northwest (NWc) and anticyclonic situations with an advection of air masses from northwest (NWA),

- the passage of various air masses during one day and/or advection of Arctic air masses,
- and the passage of a cold front or several fronts during one day.

The use of cluster analysis made it possible to identify a group of days with weather which accompanied an increased frequency in the occurrence of the analyzed phenomena. Considering the selected meteorological elements, the clearest differentiating factors in the identified clusters were atmospheric pressure and thermal conditions, followed, to a lesser extent, by cloud cover and sunshine duration, while air humidity only had a very poor differentiating effect. Wind speed was irrelevant. An increased frequency in aggressive behavior leading to coercive interventions was accompanied by the following weather types:

- in winter: high temperature ($T_{max} > 10\text{ }^{\circ}\text{C}$), i.e., days which were not typical for that season of the year, but also days with a smaller cloud cover (daily anomalies $< -4\%$), i.e., extreme weather types in terms of the meteorological conditions typical for that season of the year,
- in spring: days with temperatures within the normal range but quite overcast and humid (anomalies $> 3\%$), with the exception of April, where in terms of the thermal conditions the days should be considered cool, and in terms of cloud cover, fairly sunny,
- in summer: cold, overcast, and humid, but also hot days, with low air humidity and little cloud cover, as well as long sunshine duration, i.e., extreme weather types in terms of the meteorological conditions typical for that season of the year,
- in autumn: the least differentiated and difficult in terms of unequivocal determination; however, most frequently warm, dry, and with little cloud cover.

The increase in the frequency of aggressive behaviors ended with the use of mechanical restrains was facilitated by anomalous weather (deviating from the norm), which was not typical for the season of the year. Similar results connected with the influence of temperature were indicated in the studies of *Shiue et al.* (2016). The correlations related mainly to personality disorders, schizophrenia, and sleep disorders. There was no effect of temperature on depression and anxiety disorders. It is consistent with previous research, because in the case of the three first disorders, the personnel have to more likely deal with aggressive behavior.

The results are similar to earlier researches. There were a significant increase in pharmacological coercion during spring and mechanical coercion during summer (*Reitan et al.*, 2018). Schory et al. stated that the greatest number of visits to an emergency psychiatric service occurred in the summer, when inclement weather (as a deviation from the norms) varies from pleasant to hot and was associated with very little precipitation (*Schory et al.*, 2003). Also Finnish

research shows that the prevalence of seclusion and restraint are marked by seasonality (*Kuivalainen et al., 2017*).

The obtained results are consistent with the CLASH model (climate, aggression, and self control in humans), according to which a cooler climate correlates positively with self-restraint (*Van Lange, et al., 2017*). Others publications also noted a larger number of emergency room visits by psychiatric patients on especially hot days (*Wang and Chen, 2013; Hansen et al., 2008*) and on warm and humid ones (*Vida et al., 2012*), while a smaller number of such patients were treated on rainy days (*Santiago et al., 2005*). Weather with lower temperatures, low humidity, and low atmospheric pressure correlated with the occurrence of non-fatal violence and psychiatric admissions, but not with suicide or homicide (*Talaei et al., 2014*).

The study seems to have clinical applications. The knowledge about correlations between meteorological conditions, especially atmospheric pressure, may increase personnel awareness of the risk factors for aggressive behavior. It might influence more effective prevention of such incidents. The research allows us to determine meteorological risk factors, which are: high temperature, low air pressure, and generally – the occurrence of unusual weather in some seasons of the year.

Knowledge of the weather patterns occurring in certain months of the year would allow better preparation in the sense of the number of personnel on duty during shifts for a specific period of the year. This might be logistically difficult, however, an awareness of the risks allows for better preparation in the prevention of aggressive behavior.

The study limitations may lie in the differences between climatic and meteorological conditions in various areas of the globe as the results relate to the temperate zone of Central Europe. Specifying the patterns for other regions of the world requires additional research. The influence of atmospheric factors on the human body is universal, but an indication for future research would be the creation of similar patterns for those meteorological factors impacting on patients in other climatic zones. Earlier research has focused most often on one selected area of the globe (*Shiue et al., 2016*). Research extension could also involve a more precise analysis of the impact of weather changes depending on the time of day. Meteorological factors can have different impacts at different periods of the day, a more frequent use of coercive measures during the day than at night may be involved.

However, it needs to be emphasized that the results presented here are an attempt at a statistical processing of the correlations. Weather may lead to an increased frequency of certain behavior types exhibited by patients and staff members but, certainly, it is not the only or the decisive cause of aggression by patients who had to be subjected to coercive interventions. However, taking preventive measures should be considered in psychiatric hospitals on days when the weather is not typical for a particular season of the year and is additionally accompanied by low atmospheric pressure systems. Such weather may have an

irritating impact and may contribute to an increased likelihood of the occurrence of aggressive behavior in patients.

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