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Forecast Model of Impact of Meteorological Factors on Coronary Artery Disease Patients

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Abstract. A medical-meteorological weather assessment using hybrid spatial classification of synoptic and meteorological data was done. Empirical models for assessment as well as for forecast of medical-meteorological weather type at the seaside climatic zone in Palanga were developed. It was based on the data of meteofactors (atmospheric pressure, relative humidity, temperature, oxygen density in atmosphere, cyclone fronts, etc.) as well as on the occurrence of meteotropical reactions of cardiovascular function collected during 8-year period. The empirical models allow objectively assess and forecast 3 types of medical-meteorological weather types: favourable, unfavourable and very unfavourable weather. Classification model assessed favourable weather type in 56.1%, unfavourable in 31.7% and very unfavourable in 12.2%, while forecast was of favourable weather type in 52.4%, unfavourable in 46% and very unfavourable in 1.6% of days. Developed model enables more precise weather estimation and forecast meteotropical reactions promoting development of preventive measures of cardiovascular complications for reduction of negative weather impact on health in coronary artery diseases patients.

Key words: empirical model, medical-meteorological weather types, forecast of meteotropical reactions, coronary artery disease.

1. Introduction

Impacts of the changes of meteofactors on general health have been established by many investigators worldwide (Braga *et al.*, 2002; Bucher, 1991; Kalkstein, 2001; 2005), because meteofactors are responsible for negative impact on the development of cardiovascular and cerebrovascular complications (Braga *et al.*, 2002; Cohen and Fournier, 1989; Martinkėnas, 1994; Kalkstein, 2005). During periods of unfavourable weather conditions coronary artery disease (CAD) patients undergo meteotropical reactions (MR) and therefore they need special therapy and regime (Jendritzky and Bucher, 1992). Because of that

a system for assessment and prediction of various types of weather in respect to human health is needed. Doctors should know what kind of weather there is at present and what is expected in future. Such ability to evaluate and forecast weather medical-meteorological class or type is the aim of established biometeorological services (Martinkėnas, 1994; Jendritzky and Bucher, 1992), however, the practical use of methods for weather medical type estimation and forecast prepared by the foreign scientists in Lithuania is complicated because every geographical location is characterized by its own specific climatic and local weather peculiarities. Therefore, the modelling of weather medical-meteorological type and forecast may give the instrument for medics to introduce preventive measures and improve human health.

The aim of the work was to develop a model for the weather medical-meteorological and forecast assessment in order to control and prevent the manifestation of meteotropical reactions in CAD patients.

2. Object of the Study

The meteorological, heliogeophysical factors and data of atmospherically changes were used to describe climatic and weather situation. The study has covered the period from 1980 to 1990. Daily meteorological data were registered at Palanga Bioclimatic station during the main hours of observation (at 2, 8, 14, 20 hours at local time during autumns-winter period and 1 hour later during spring-summer period). The following meteorological parameters were used: weather temperature, absolute and relative humidity, atmospheric pressure, wind speed. Data of changes of baric systems (dates of anticyclone intrusion and cyclonic front movement at sea-side) were provided by Lithuanian Hydro meteorological centre.

Data on Earth magnetic field and solar activity were provided by IZMIRAN institute, Kaliningrad observatories. Solar activity indices W (Wolf index – relative number of Sun-spots) and Solar radio flux 3000 MHz. Geomagnetic field data: Σk indices (Earth magnetic field variations, in scale numbers every 3 hours, summed in a twenty-four hours) and data on geomagnetic storm.

During the five year period for 2108 CAD patients were registered 4070 cases of MR (1673 (79.4%) men and 435 (20.6%) women). Data on anamnesis showed that 61.0% of CAD patients during rehabilitation treatment in Palanga had performed meteotropical responses and 61.2% sensitivity to climatic change. During in-hospital rehabilitation every patient with meteotropical responses had impact of 3–4 MR events on average. MR, symptoms clinical examination, subjective complaints were registered every morning.

2.1. *Statistical Analysis*

Data presented mean $\pm 95\%$ CI. Bivariate comparisons were performed using Student's t tests for interval variables. Mann-Whitney U tests for no normally distributed variables. One or two factor ANOVA was used to assess differences between variables of more

than 2 independent groups. Kruskal Wallis test was used, when appropriate. For multiple paired comparisons we have used Bonferroni correction for multiple comparisons. A value of $p < 0.05$ was considered statistically significant.

3. Algorithm for Medical-Meteorological Weather Type Assessment and Forecast

3.1. *Algorithm for Medical-Mmeteorological Weather Type Assessment*

Weather medical types were classified – divided into different groups according to sensitivity of MR rate. The following algorithm for medical-meteorological weather type assessment was developed (Fig. 1).

Cluster analysis was applied to the meteorological factors time series in order to group objectively days with similar weather conditions. Clustering by weather temperature, relative humidity, barometric pressure and wind speed enabled the creation of the basis of the weather medical type classification method. The aim of this method is to maximize the homogeneity of objects within the clusters and also to maximize the heterogeneity

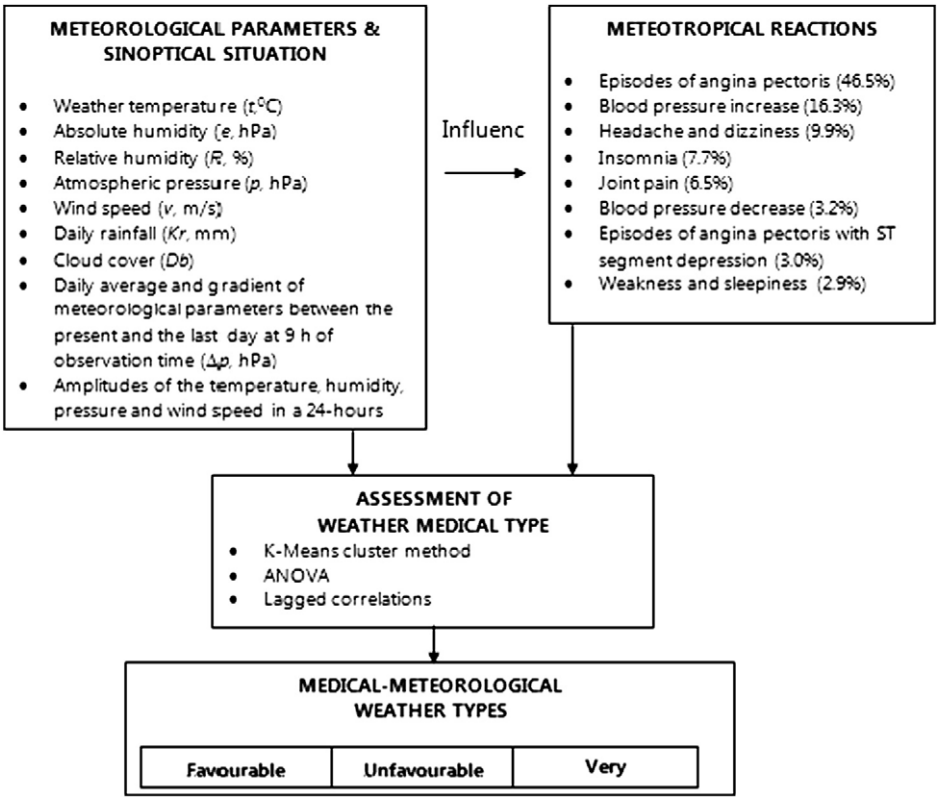

Fig. 1. Block scheme of algorithm for medical-meteorological weather type assessment.

between the clusters. Each day observation corresponds to a point in the m-dimensional space (Kalkstein *et al.*, 1987; 1990; Makra *et al.*, 2006). The characterization of a distance between two observations j and k as "close" or "far" is determined by the square of their Euclidean distance:

$$d_{jk}^2 = \sum_{i=1}^{m} (x_{ji} - x_{ki})^2 ,$$

where x_{ji} is the value of the ith factor for the jth day and x_{li} is the value of the ith factor for the kth day.

Weather situations during 24-hours period effecting the meteotropical reactions rate (more often or less often) were defined by K-means cluster method (measure of similarity – Euclid distance quadrate). Established rules were followed while classifying weather types: a) algorithm of estimation and forecast of weather medical types must be simple and objective as much as possible for use it in practice; b) weather medical types should reflect real weather state dynamics; c) dynamics of meteotropical reactions at a separate weather medical types must clearly divers; d) clear and understandable criterion in weather medical types and forecast algorithm must be used, since the meteorological centres provides the main meteorological parameters (weather temperature, relative humidity, atmospheric pressure, wind speed, etc.) as whole numbers, though forecasted intervals are quite wide.

Meteorological parameters were classified into 5 types, according to weather temperature, relative humidity, barometric pressure and wind speed. Quantity of parameters and types depended on groups significantly representing weather states (Fig. 2). Highest MR frequency was in the 1st (2.81 ± 0.12) and 2nd weather type (2.47 ± 0.11), lowest – in 4th (2.03 ± 0.16) and 5th (2.06 ± 0.09). In 3rd weather type MR frequency was insignificantly higher than total average. It is agreed that 4th and 5th weather types are more favourable for CAD patients, comparing them with the 1st and 2nd. It is accepted that

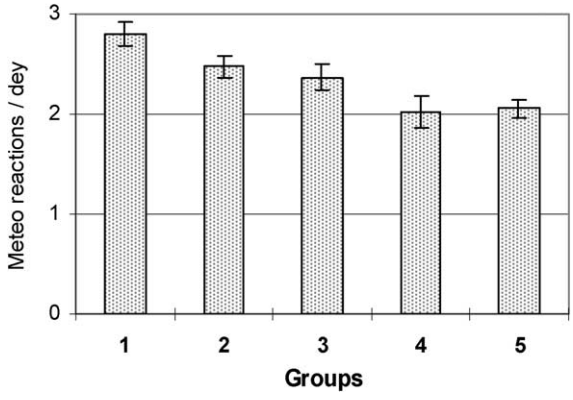

Fig. 2. Meteotropical reactions rate in groups (clusters) classified by K-means cluster analysis. $p < 0.01$ between 1 and 4, 5; 2 and 5 groups; $p < 0.05$ between 1 and 3; 2 and 4; 3 and 5 groups.

favourable weather conditions are under weather temperature higher than annual average and relative humidity close to average. Either the high barometric pressure (1020.9 hPa), during anticyclone situations, or close to annual average (1011.3 hPa), MR frequency was approximately the same (4 and 5 types). Unfavourable wither though is considered when weather temperature is below zero, since MR are 38.4% more frequent than in 4th type. In this weather type wind speed is low, barometric pressure is high, and amplitude is higher then annual average (4.6 hPa).

The 2nd weather type was established when weather temperature is close to 0°C, barometric pressure is lower then annual average and its amplitude > 6.2 hPa. Following MR frequency the 2nd weather type is unfavourable for patients. The 3rd weather type is characterized by considerable dynamics of the barometric pressure and wind speed in 24 hours period. This kind of weather is observed when average weather temperature is close to 4.3 ± 0.3°C. This weather type is unfavourable to CAD patients, since MR frequency is up to 16.0% ($p < 0.05$) higher than in the 4th and 5th weather types.

Regarding the synoptic circulation patterns over Lithuanian sea-side, the classification of weather types according to gradient of barometric pressure between successive days (Fig 3.), had shown that there were 61.2% of relatively favourable weather conditions (when $\Delta p < |6|$ hPa), unfavourable – 22.6% (when $|6| < \Delta p < |10|$ hPa) and very unfavourable – 16.2% (when $\Delta p > |10|$ hPa). It was shown that for CAD patients in Palanga there were 32.5% days/year of unfavourable and very unfavourable weather conditions during cyclones and anticyclones situations, and when barometric pressure has been changing in a few days period more than |6| hPa – 38.6% days/year were registered. When clear cyclonic front was passing, when barometric pressure deviation was $\Delta p > |8|$ hPa, unfavourable and very unfavourable weather recurrence reached 18.6%; when anticyclones situations interrupted – 13.9% and with geomagnetic storms – 10.4% (Fig 4.).

Practical experience in evaluating and forecasting 24-hour weather according to favour and unsavoury to CAD patients has shown that 3 weather medical types are suffi-

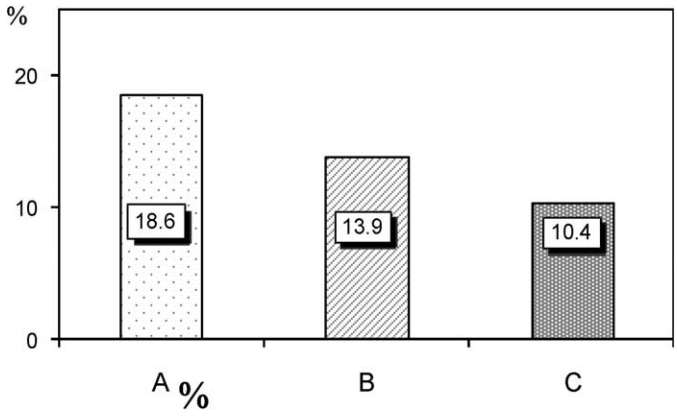

Fig. 3. Unfavorable and very unfavorable weather rate (%) to CAD patients during cyclones (A), anticyclones (B) activity and geomagnetic storms (C).

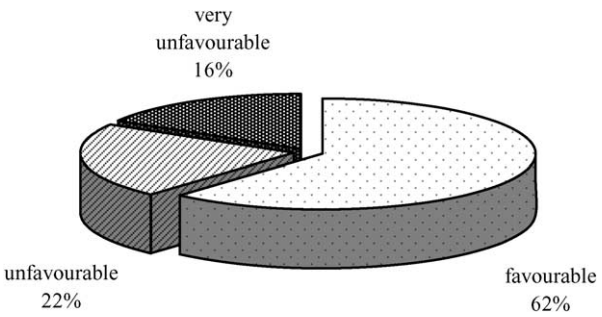

Fig. 4. Unfavorable and very unfavorable weather rate (%) according to changes of barometric pressure per day. $\Delta p \leqslant |\ 6\ |$ hPa – favorable; $|6| \leqslant \Delta p \leqslant |\ 10\ |$ hPa – unfavorable; $\Delta p \geqslant |\ 10\ |$ hPa – very unfavorable.

cient. Because of that we shifted from 5 to 3 types of medical-meteorological weather class assessment: favourable, unfavourable and very unfavourable. When presenting biometeorological information, a short comment on meteorological conditions is provided, an algorithmic estimation of the last 24-hours weather medical type is given and weather medical type for the next 24-hours is forecasted. For the estimate of weather medical type a following empirical model is created (Diagram 1):

1. ***Favourable medical weather type***: during anticyclones situations troposphere's fronts are absent. The main meteorological parameters (weather temperature, barometric pressure, relative humidity, wind speed) dynamics are even – alteration of amplitudes in 24-hours period did not exceed observed average values of many years at the same season. A gradient of barometric pressure in a 24-hours period (difference between indices at 9 h of observation time) $< |6|$ hPa. Relative humidity $< 85\%$, wind speed was less than 6 m/s (by averages in a 24-hours period).

2. ***Unfavourable medical weather type***: a) the changes of weather evaluated by barometric pressure gradient' alteration in a 24-hours period, not less than |6| hPa; b) when relative humidity is higher than 90%, wind speed is higher than 6 m/s, gradient of barometric pressure in a 24-hours is not less than |4| hPa; c) when average weather temperature in 24-hours is lower than -2^0C, wind speed is getting until 3–4 m/s, its directions is varying from south-east to south-west and gradient of barometric pressure in 24-hours is not lower than |4| hPa.

3. ***Very unfavourable medical weather type***: the weather shifts in sharp opposition, and this shift is followed by the alteration of gradient of barometric pressure more than|10| hPa in 24-hours period, while wind speed is not less than 8 m/s and daily rainfall $\geqslant 1$ mm.

The empiric model of the algorithm is shown in Diagram 1, when At=4°C, AR=17%, Av=4 m/s – averages of amplitudes of weather temperature, relative humidity and wind speed per year are expressed in whole numbers. Meteorological services provide meteorological parameters in a whole numbers (decimal parts are approximated, if no special agreement is done), though in the 3rd weather type of this model (very unfavourable) limit of day-to-day alteration of barometric pressure is agreed as $\geqslant |\ 11\ |$ hPa. In any case the precision of the objective definition of the weather medical type depends on the pre-

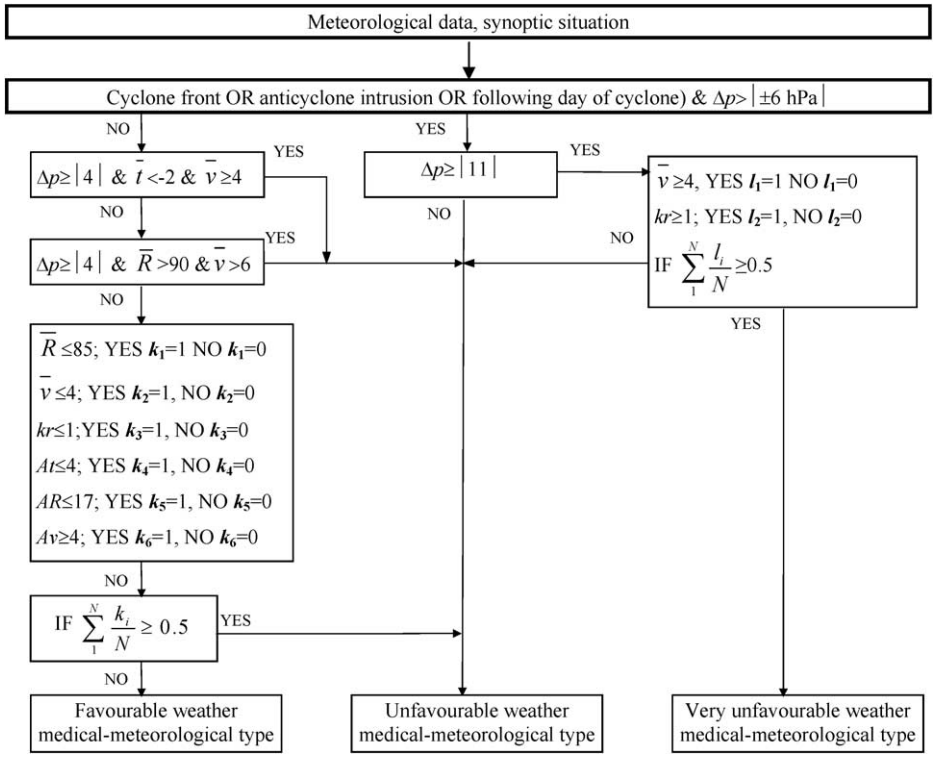

Diagram 1. The empirical model of the weather medical type's estimate. Δp, hPa – change of barometric pressure between the present and the last day at 9 h of observation time; $\overline{t}$, ^{0}C – daily average of weather temperature; $\overline{R}$, % – daily average of relative humidity; $\overline{v}$, m/s – daily average of the wind speed; *Kr*, mm – daily rainfall; *At*, *AR*, *Av* – amplitudes of the weather temperature, relative humidity and wind speed in a 24-hours period.

cision of provided meteorological information and the precision of the weather medical type estimation model.

3.2. *Algorithm for Prognosis and Awareness Medical-Meteorological Weather Type*

Block scheme of algorithm for prediction and awareness of medical-meteorological weather types forecast and meteotropical reactions is presented in Fig. 5.

For the forecast of the weather medical type's data of meteorological parameters and meteorological forecast are used. A short-time weather forecast is easy prepared when atmospherically processes changes slightly or do not changes at all (mostly – anticyclone weather). When a cyclonic weather is observed, the weather characteristics changes very quickly – temperature, pressure, cloudiness, daily rainfall, wind direction and speed, etc., and to give a precise weather forecast is quite complicated. For the forecast of the weather medical type the following algorithm is presented (Diagram 2):

1. ***Favourable weather medical type is forecasted***: troposphere fronts are absent and they are not forecasted (when anticyclone situation is prevailed). During the last day the

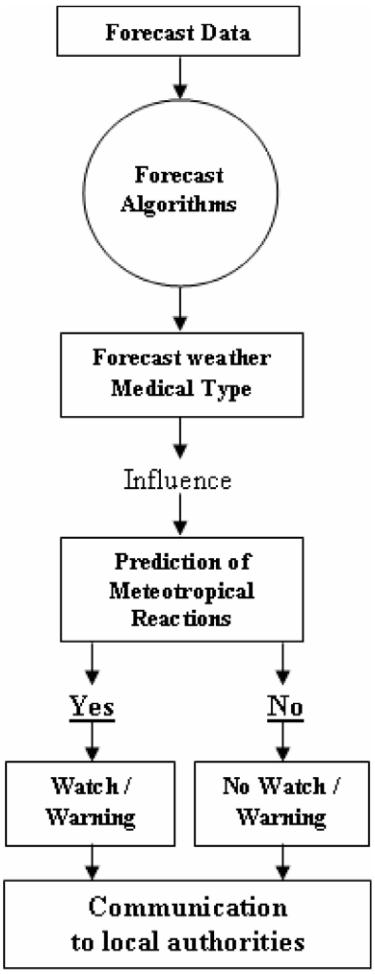

Figure 5. Block scheme of algorithm for prediction and awareness of medical-meteorological weather types forecast and meteotropical reactions.

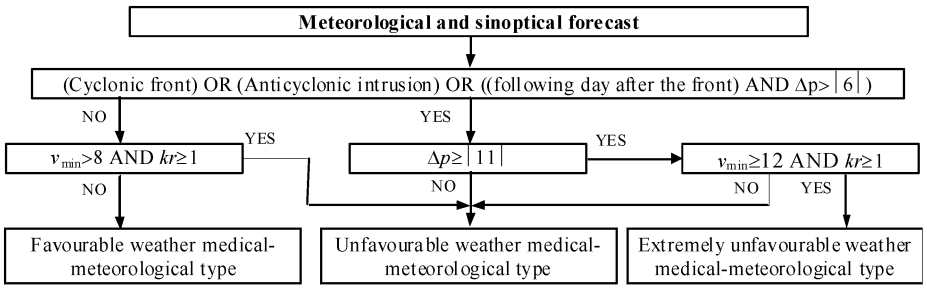

Diagram 2. The empirical model of the weather medical types forecast. Δp (hPa) – change of barometric pressure between the present and following day (sinoptical data); $v_{\min}$ (m/s) – minimal wind speed (data of meteorological forecast); kr (mm) – daily rainfall (data of meteorological forecast).

dynamism of the main meteorological parameters was even – alteration of amplitudes did not exceed registered average values of many years. Meteorological forecast information: daily rainfall is not forecasted, wind speed is forecasted at 3–8 m/s.

2. ***Unfavourable weather medical type is forecasted***: if very unfavourable weather type prevailed during the last day, a move of atmospherically front and intrusion of anticyclone situation is forecasted in synoptically map. Meteorological forecast information: is forecasted change of weather, followed by strengthening wind speed from 7–12 to 15 m/s, increase of cloudiness or sharp fall of temperature, daily rainfall is possible ($\geqslant 1$ mm).

3. ***Very unfavourable weather medical type is forecasted***: clearly defined move of atmospherically front is forecasted in synoptically map (change of atmospherically pressure can reach $> |10$ hPal. Meteorological forecast information: abundant daily rainfall, strong, rushy wind (7–12 m/s, with rushes up to 15–20 m/s or more).

The precision of the weather medical types forecast is directly related with the precision of both, the meteorological forecast and synoptical data. Local meteorological services provide forecasts in which possible values of the main meterological parameters (weather temperature, wind speed and cloudiness) alternate in a range which is not lower than their amplitude averages at the corresponding month. Therefore use of these parameters for the forecasting of weather medical types is limited. The use of synoptically data is more reliable in this case.

Exact assessment of weather types for CAD patients is useful for medical staff and increases significance of the weather medical type's prognosis. Incorrect forecast of favourable weather medical type was not less then 5 cases of MR manifestation, though the weather medical type was assessed as unfavourable. This is the most complicated error case that reduced trust of the doctors into available biometeorological information. On the other hand, the work of biometeorologist became even more difficult when there was important to evaluate weather medical type during its dynamics, while referring on level of different meteorological parameters. The frequency of manifestation of meteotropical reactions on such day revealed relative precision of the assessment of weather medical types. Not a substantial error was recorded when the weather medical type was forecasted as unfavourable, but eventually it appeared as favourable. The practical work has demonstrated that simple and clear criteria are required in order to evaluate and forecast weather medical types for CAD patients objectively.

The weather medical type assessment and forecast model is verified by comparing forecasted and evaluated weather medical types (Table 1). Favourable weather types were forecasted 52.4%, unfavourable – 46% and very unfavourable – 1.6% days only. By using weather medical type classification model, 56.1% of days were evaluated as favourable, 31.7% – as unfavourable and 12.2% – as very unfavourable weather types.

It is obvious that recurrence of very unfavourable weather types is lower, and of unfavourable weather types – higher then that established by relative classification according to the barometric pressure gradient gradations, because of a more accurate description of the 3rd (very unfavourable) weather type and because of inclusion of some weather situations (at the winter when weather temperatures were negative) into the 2nd (unfavourable). The recurrence percent of favourable weather type had slightly increased.

Table 1
Results of estimation and forecast of weather medical types

Biometeorological information	Favourable weather types		Unfavourable and very unfavourable weather types	
	identified N (%)	unidentified N (%)	identified N (%)	unidentified N (%)
Forecasted medical weather types	76 (40.2)	23 (12.2)	47 (24.9)	43 (22.7)
Estimated medical weather types	98 (51.9)	8 (4.2)	55 (29.1)	28 (14.8)

Precision of assessment of MR by biometeorologist and medical doctor differ. From the point of view of medical doctor, at the chosen limit of MR cases biometerological forecast was confirmed in 65.1% cases without distribution meteorological weather into different types, while from the point of view of biometeorologist there were 76.8% cases identified when forecasting favourable weather types and 52.2% – forecasting unfavourable and very unfavourable. Developed method demonstrated correct assessment of favourable weather types at 92.5%, and unfavourable and very unfavourable – at 66.3%.

It should be taken into account, that even if there are conclusions of practical value, an application of medical-meteorological information is more of stochastic nature and there are a lot of biometeorology science problems to be solved. Introduced weather medical type classification is simple and understandable. The objective weather medical type classification, based on the change of synoptically reactions, enables use of this weather medical type forecast and estimation method in other Lithuanian climatically areas.

4. Conclusions

The algorithm and empirical model for medical-meteorological weather type assessment and forecast were developed using meteorological and synoptically data of sea-side geographical area of Lithuania. The empirical model allows objectively assess and forecast 3 types of medical-meteorological weather types: favourable (56.1% and 52.4%), unfavourable (31.7% and 46.0%) and very unfavourable weather (2.2% and 1.6% of days, correspondingly for assessment and forecast).

Developed model demonstrated correct assessment of favourable weather types at 92.5%, and unfavourable and very unfavourable – at 66.3%. Adequacies of assessment of medical-meteorological weather type were 76.8% for favourable and 52.2% for unfavourable and very unfavourable weather types, while the adequacy of estimation of meteotropical reactions by medical doctor was lower (65.1%).

Developed model enables more precise weather estimation and forecast meteotropical reactions promoting development of preventive measures, reducing weather impact on health in coronary artery diseases patients.

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Klimato veiksnių įtakos sergantiems koronarine liga prognozavimo modelis

Arvydas MARTINKĖNAS, Vytautas KAMINSKAS, Giedrius VARONECKAS

Sudaryti medicininių-meteorologinių orų tipų įvertinimo ir prognozavimo empiriniai modeliai. Algoritmo ir modelio pagalba objektyvizuotas orų medicininių-meteorologinių tipų įvertinimas ir prognozavimas. Sudarytas orų medicininių-meteorologinių klasių įvertinimo bei prognozavimo empirinis modelis įgalina tiksliau vertinti ir prognozuoti orus pagal jų palankumą (ar nepalankumą) sergantiems išemine širdies liga, tuo padėdamas meteoprofilaktikos vykdymui, mažinant orų įtaką ligoniams, sergantiems išemine širdies liga atstatomojo gydymo etape Lietuvos pajūryje (Palanga).