

## METHODS OF THE ESTIMATED TWO-PARAMETER LINEAR REGRESSION MODELS FOR DIAGNOSIS OF BRONCHIAL ASTHMA SEVERITY IN CHILDREN

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Received: 30 November 2020, Revised and Accepted: 22 December 2020

### ABSTRACT

**Objectives:** Prognostication of bronchial asthma severity in children by means of two-parameter regression models building.

**Methods:** A clinical study of 70 children with bronchial asthma diagnosis of 6 to 18 years old was done. 142 factors were analyzed and a degree of relationship among them was revealed. Single-factor regression models were used during preliminary experimental data processing.

**Results:** The correlation connection between the value observed and the factors under research was revealed. The method of two-parameter linear models with a fair accuracy was developed.

**Conclusion:** The suggested method of approximate two-parameter linear regression models can be used for preliminary analysis of medical research data where the value observed depends on a big number of loosely connected factors.

**Keywords:** Asthma, Child, Regression model.

### INTRODUCTION

Bronchial asthma (BA) is a heterogeneous inflammatory respiratory disease with more than 300 million people currently affected [1, 2]. Despite years long studies asthma is still the most widespread chronic disease within pediatric population in different countries, and the disease incidence increases with each passing year [3, 4]. Patients' quality of life significantly decreases and is followed by tangible economic costs both for a family and for the society [5, 6, 7]. Notwithstanding a significant progress in the disease treatment, asthma still remains one of the most frequent reasons of invalidity in pediatrics [8, 9]. Currently, not only the disease control but also revealing of pathogenetic connections and triggers for preventive activities planning are still remain relevant. Prediction of asthma onset and course in children is still difficult due to a multi factorial nature of disease [10]. Early disease manifestation as well as similarity of clinical manifestations with other diseases of primary school age impede timely diagnosis [11-17]. If children with an undiagnosed BA get a long and improper treatment, preventive and therapy measures are placed on too late and it affects the quality of life of both a patient and their family [18, 19]. Early detection of patients with a high risk of disease progressing allows to use individual therapy and observation methods and helps to provide reliable control of asthma. Regardless significant achievements in understanding of asthma genetics, etiology and pathogenesis, there are still patients with severe course of asthma and poor disease control. Numerous clinical studies of uncontrolled asthma course prove the necessity of analyzing the factors causing strong forms of asthma [20-23]. To increase the study quality, analyzing requires improving both the models themselves and methods of their building. Linear regression models are a common method of severity of bronchial asthma diagnosis. Refinement of the results is possible by using regression models containing two or more factors. However, this approach leads to additional calculations in the

amount nonlinearly depending on the number of factors. The complexity and laboriousness of linear multivariate models building result to the fact that the model data are used less often in the initial evaluation and analysis of data.

It is generally accepted that it is difficult to predict the severity of bronchial asthma due to influence of a large number of factors that are loosely connected. This particular fact allows to develop rather accurate and efficient evaluative multiple linear models for diagnosis of bronchial asthma severity.

In this paper, we propose a method of two-parameter linear models on the basis of pair wise regression models and estimate their error.

### METHODOLOGY

The results of the study involving 90 children aged from 6 to 17 years 11 months and 29 days were used as a dataset for linear two-parameter regression models. 70 children with diagnosed BA were included into the main group. The control group contained 20 healthy children. The average age of children with BA was  $11.0 \pm 3.7$  years. The workup included the study of patients' parents complaints and medical and life history by means of interviewing patients' parents as well as clinical features of disease course and results of clinical and laboratory examinations in dynamics of the disease. The study was conducted with respect for human rights and international ethical requirements; it does not violate ethical norms in science and standards for conducting biomedical research.

The data were originated to build a regression model. The raw data from experimental studies are presented in Table 2. Individual patient data are encoded. Before the experiment, the factors that could influence on severity of bronchial asthma were determined [10]. These factors, with a total of 142, are divided into categories

(Table 1) allowing to unify the data analysis and structure connections among them (Fig. 1 – Fig. 6).

**Table: 1 Classification of factors**

id	Description	Common Information
1	Course type	Severe persistent, Moderate persistent, Mild persistent, Intermittent
2	Principal diagnosis(case taking)	Atopic dermatitis, Allergic rhinitis, Deflection of nasal septum, Secondary cardiomyopathy
3	Anamnesis of disease	Number of years from the first symptoms
4	Anamnesis of life	Bronchial asthma in mother, Bronchial asthma in father, Allergic rhinitis in mother, Allergic rhinitis in father, Bronchial asthma in relatives of second generation
5	Complete blood count	RBC, HBC, WBC, Eosinophils %, Basophils %, Band neutrophils %, Segmented neutrophils %, Lymphocytes %, Monocytes %, ESR
6	Urinalysis Test	Color, Appearance, Specific gravity, pH, Leukocytes, Transitional epithelial cells, Mucus
7	Skin allergy test(pollen allergens)	Chenopodium, Sagebrush, Birch, Timothy, Cock's-foot, Elytrigia, Ryegrass, Alder, Sunflower, Fescue grass, Walnut, Rye, Linden, Nettle, Dandelion, Sump weed, Plantain, Foxtail, Ragweed, Chestnut, Cypress, Maple
8	Skin allergy test(household allergens)	Pillow feather, Domestic dust, Rabbit hair, Cat hair, Dog hair, Sheep wool, Daphnia
9	Food allergy test	Carp fish, Pollack fish, Egg white, Milk, Apple, Raspberries, Beetroot, Cabbage, Beef, Lemon, Pork, Banana, Watermelon, Orange, Chicken, Tangerine, Cocoa, Soybeans, Black tea, Grape, Tomato, Rice groats, Buckwheat grits, Beans, Wheat groats, Oat grits, Corn grits, Rye grits
10	Ig E	Serum immunoglobulin E
11	Spirogram	VC, FVC, PEF, FEF(MEF) 25%, FEF(MEF) 50%, FEF(MEF) 75%, FEV 25-75%, FEV1, FEV/FVC %, MVV.
12	Immunological status	Leukocytes, Neutrophils(%;10 <sup>3</sup> cells), Lymphocytes(%;10 <sup>3</sup> cells), CD3(%;10 <sup>3</sup> cells), CD4(%;10 <sup>3</sup> cells), CD8( %;10 <sup>3</sup> cells), CD16(%;10 <sup>3</sup> cells), CD22(%;10 <sup>3</sup> cells), CD25(%; 10 <sup>3</sup> cells), IgA, IgM, IgG, Phagocytosis of latex, %, Phagocytic number, Total complement (CH 50), CIC with 3.5% PEG, units., Spontaneous NBT tests, %, Spontaneous IAN tests, units., Stimulated NBT test, %, Stimulated IAN test, units, Lysosomal cationic proteins, units
13	TSLP	The level of serum thymic stromal lymphopoietin
14	Age	Age of the examined children from 6 to 17 years
15	Gender	Surveyed 56 boys and 14 girls

A large number of factors determining a specific feature are coded with a value of 0 or 1. In the above analysis, there are also factors that can take on values corresponding to several states. Thus, for example, the factor [8.Pillow feather] characterizes four degrees of severity of the skin allergy test, each of its states is coded in the order of increasing. The number in front of the factor name determines the category the factor belongs to.

Factors that occurred as a result of clinical trials in no more than two patients were excluded from the analysis of the raw data. The list of excluded factors is presented in Table 2. The factors excluded are expected to have a small effect on the data analysis result and may not be considered. This allowed to reduce the total number of factors to be analyzed by ~ 10%.

**Table: 2. List of excluded factors**

id	Description	Number of Patients with the Factor	Category of Factor (Table1)
1	Vasomotor rhinitis	2	2. Principal diagnosis (case taking)
2	Allergic Rhino sinusitis	2	
3	Corn	2	
4	Acacia	2	7.Skin allergy test(pollen allergens)
5	Willow	1	
6	Sorrel	2	
7	Hazel	2	
8	Egg yolk	2	
9	Hake	2	9.Food allergy test
10	Cucumber	2	
11	Carrot	2	
12	Potatoes	2	

The data set was split into two parts. To build a regression model, the data set was used and to check the adequacy of the regression model data set was used.

When choosing the factors of the regression model, let's use-

$$r_{y x_m} \rightarrow \max, \quad r_{x_m x_v} \rightarrow \min, \quad (1)$$

$$r_{x_m y} = \frac{K_{x_m y}}{\sqrt{D_{x_m} D_y}}, \quad r_{x_m x_v} = \frac{K_{x_m x_v}}{\sqrt{D_{x_m} D_{x_v}}}, \quad (2)$$

$$D_{x_m} = \frac{1}{n} \sum_{i=1}^n (X_{m i} - m_{x_m})^2,$$

$$K_{x_m x_v} = \frac{1}{n} \sum_{i=1}^n (X_{m i} - m_{x_m})(X_{v i} - m_{x_v})$$

$$m_{x_m} = \frac{1}{n} \sum_{i=1}^n X_{mi}, \quad m_y = \frac{1}{n} \sum_{i=1}^n Y_i, \quad (3)$$

where  $r_{y x_m}$  is the coefficient of correlation between the observed factor  $Y$  and the regressor  $X_m$ ;  $r_{x_m x_v}$  is correlation coefficient between regressor  $X_m$  and regressor  $X_v$ ;  $K_{x_m y}$  is covariance between the observed factor  $Y$  and the regressor  $X_m$ ;  $K_{x_m x_v}$  is covariance between regressor  $X_m$  and regressor  $X_v$ ;  $D_y$  is

variance for the observed factor  $Y$ ;  $D_{x_m}$  is variance for the regressor  $X_m$ ;  $m_y$ ,  $m_{x_m}$  are means for the observed value  $Y$  and the regressor  $X_m$ .

The set of factors in accordance with criterion (1) is shown in Table 3.

Table: 3 Factors

	2.Atopic dermatitis	4.Bronchial asthma in relatives of second generation	2.Allergic rhinitis	8.Sheep wool	8.Domestic dust	8.Rabbit hair	8.Pillow feather
2.Atopic dermatitis	-	-0,0778	0,1147	0,1969	0,131	0,2282	0,666
4.Bronchial asthma in relatives of second generation	-0,0778	-	0,078	0,1338	0,2677	0,0077	0,2606
2.Allergic rhinitis	0,1147	0,078	-	-0,0414	0,1835	0,1266	0,0193
8.Sheep wool	0,1969	0,1338	-0,0414	-	0,1636	0,3102	0,2804
8.Domestic dust	0,131	0,2677	0,1835	0,1636	-	-0,0391	0,2025
8.Rabbit hair	-0,2282	0,0077	0,1266	0,3102	-0,0391	-	0,084
8.Pillow feather	-0,666	0,2606	0,0193	0,2804	0,2025	0,084	-
Severe	0,4336	0,3024	0,31	0,3245	0,3206	0,2394	0,3437

The criterion  $r_{y x_m} \rightarrow \max$  is determined for the observed value [1.Severe persistent] and the regressor. According to the first  $r_{y x_m} \rightarrow \max$  and second  $r_{x_m x_v} \rightarrow \min$  conditions, four factors of the model are selected: [2.Allergic rhinitis ], [8.Sheep wool ], [8.Rabbit hair], [4.Bronchial asthma in relatives of second generation].

The regressors the absence of a connection with the explained factor is assumed for are presented in Table 4. For these factors, the correlation coefficient tends to zero  $r_{y x_m} \rightarrow 0$

Table: 4. Regressors assumed as not having connection with the explained factor.

№	Perpeccop, $X_1$	№	Perpeccop, $X_1$
1.	9.Blacktea	9.	6.Specific gravity
2.	6.Appearance	10.	9.Apple
3.	7.Walnut	11.	7.Sunflower
4.	otalcomplement (CH 50)	12.	6.Transitional epithelial cells
5.	7.Sagebrush	13.	12.IgA
6.	12.Lymphocytes, 10*3 cells	14.	8.Daphnia
7.	2.Defiection of nasal septum	15.	5.Segmented neutrophils, %
8.	4.Bronchial asthma in mother		

**One-parameter linear model**

The linear pair wise regression model for the observed value  $Y$  and the regressor  $X_m$  has the form

$$y = a + b_m x_m, \quad (4)$$

$$a = m_y - m_{x_m} b_m, \quad b_m = \frac{K_{x_m y}}{D_{x_m}}, \quad (5)$$

With the values of the coefficients  $a$  и  $b_m$ , which are determined taking into account formulas (2), (3).

An increase in the absolute value of the covariance coefficient leads to an increase in the relationship between the parameters  $Y$  и  $X_m$ . Let's go to new variables

$$\xi_m = \frac{x_m - m_{x_m}}{\sqrt{D_{x_m}}}, \quad \eta = \frac{y_1 - m_y}{\sqrt{D_y}},$$

$$\sigma_{x_m} = \sqrt{D_{x_m}}, \quad \sigma_y = \sqrt{D_y}, \quad (6)$$

Then the dependence between the parameters can be represented in a simpler form

$$\eta = r_{y x_m} \xi_m, \quad -1 \leq r_{y x_m} \leq 1, \quad (7)$$

Where  $r_{y x_m}$  is the correlation coefficient between the parameters  $Y$  и  $X_m$ , corresponds to the degree of linear dependence of the parameters themselves;  $\sigma_{x_m}$ ,  $\sigma_y$  are standard deviations. The magnitude of the value  $r_{y x_m}$  sets the degree of tightness of the linear relationship.

**Two-parameter linear model**

The two-parameter linear regression model for the observed value  $Y$  and two regressors  $X_m$ ,  $X_v$  has the form

$$y = a + b_m x_m + b_v x_v. \quad (8)$$

In consideration of

$$\sum_{i=1}^N y_i = a \sum_{i=1}^N 1 + b_m \sum_{i=1}^N x_{mi} + b_v \sum_{i=1}^N x_{vi}, \quad (9)$$

$$m_y = a + b_m m_{x_m} + b_v m_{x_v}, \quad (10)$$

And using notation (6), let's write the equations of the two-parameter linear model in the dimensionless form

$$\eta = \beta_m \cdot \xi_m + \beta_v \cdot \xi_v, \quad (11)$$

$$\beta_m = b_m \frac{\sqrt{D_{x_m}}}{\sqrt{D_y}}, \quad \beta_v = b_v \frac{\sqrt{D_{x_m}}}{\sqrt{D_y}}. \quad (12)$$

Coefficients  $\beta_m$  and  $\beta_v$  are determined from the system of equations

$$\begin{cases} \sum_{i=1}^N (\eta_i - \beta_m \xi_{mi} - \beta_v \xi_{vi}) \xi_{mi} = 0, \\ \sum_{i=1}^N (\eta_i - \beta_m \xi_{mi} - \beta_v \xi_{vi}) \xi_{vi} = 0, \end{cases} \begin{cases} \beta_m \frac{\sum_{i=1}^N \xi_{mi}^2}{N} + \beta_v \frac{\sum_{i=1}^N \xi_{mi} \xi_{vi}}{N} = \frac{\sum_{i=1}^N \eta_i \xi_{mi}}{N}, \\ \beta_m \frac{\sum_{i=1}^N \xi_{mi} \xi_{vi}}{N} + \beta_v \frac{\sum_{i=1}^N \xi_{vi}^2}{N} = \frac{\sum_{i=1}^N \eta_i \xi_{vi}}{N}. \end{cases}$$

Which can be represented as

$$\begin{cases} \beta_m + \beta_v \cdot r_{x_m x_v} = r_{y x_m}, \\ \beta_m \cdot r_{x_m x_v} + \beta_v = r_{y x_v}. \end{cases} \quad (13)$$

Let us solve the system of equations (13) for the unknowns  $\beta_m, \beta_v$ :

$$\beta_m = \frac{r_{y x_m} - r_{y x_v} r_{x_m x_v}}{1 - (r_{x_m x_v})^2}, \quad \beta_v = \frac{r_{y x_v} - r_{y x_m} r_{x_m x_v}}{1 - (r_{x_m x_v})^2}. \quad (14)$$

Coefficients  $a, b_m, b_v$  are determined from expressions (10), (12)

$$b_m = \sqrt{\frac{D_{x_m}}{D_y}} \frac{r_{y x_m} - r_{y x_v} r_{x_m x_v}}{1 - (r_{x_m x_v})^2}, \quad b_v = \sqrt{\frac{D_{x_v}}{D_y}} \frac{r_{y x_v} - r_{y x_m} r_{x_m x_v}}{1 - (r_{x_m x_v})^2}, \quad (15)$$

$$a = m_y - b_m m_{x_m} - b_v m_{x_v}. \quad (16)$$

Coefficients  $a, b_m, b_v$  determine the equation of a two-parameter linear model, presented in dimensional form. Coefficients  $\beta_m$  and  $\beta_v$  are used for a two-parameter linear model, the parameters of which are presented in dimensionless form.

Linear two-factor equations (8) for diagnosing the severity of bronchial asthma disease are shown in Fig. 1 - Fig. 6.

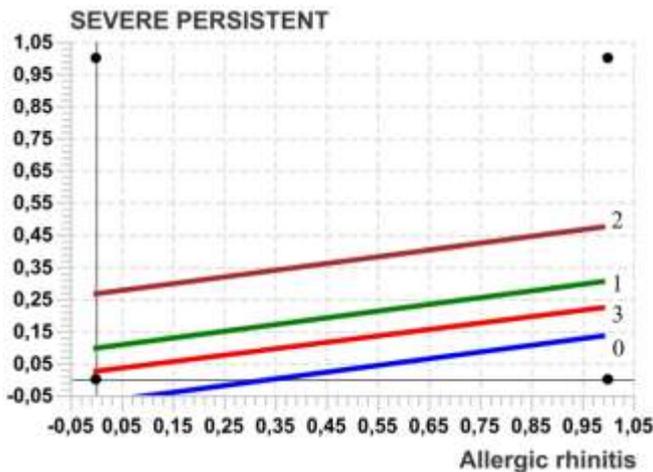


Fig. 1: Two-parameter model  $y = -0,07 + 0,21x_1 + 0,17x_2$ ,  $x_2 = \{0; 1; 2\}$  (Table 2), one-parameter model  $y = 0,025 + 0,2x_1$ ,  $x_2 = 3$  (Table: 1)

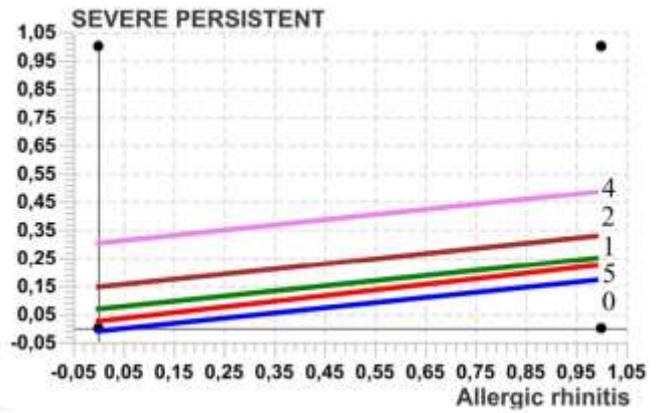


Fig. 2: Two-parameter model  $y = -0,01 + 0,18x_1 + 0,08x_2$ ,  $x_2 = \{0; 1; 2; 4\}$  (Table 2), one-parameter model  $y = 0,025 + 0,2x_1$ ,  $x_2 = 5$  (Table: 1)

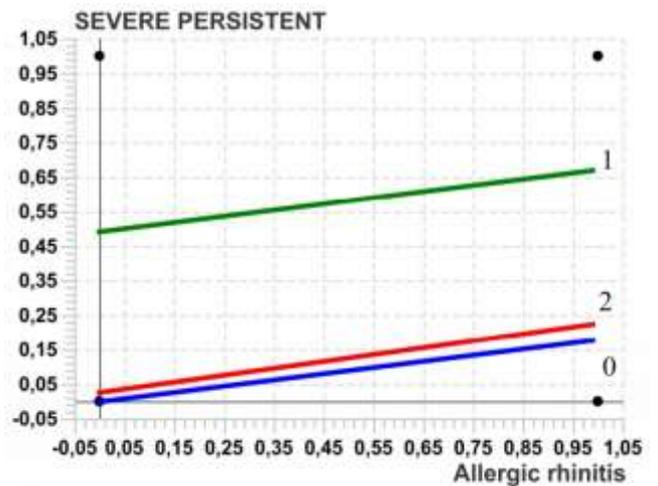


Fig. 3: Two-parameter model  $y = 0,18x_1 + 0,49x_2$ ,  $x_2 = \{0; 1\}$  (Table 2), one-parameter model  $y = 0,025 + 0,2x_1$ ,  $x_2 = 2$  (Table: 1)

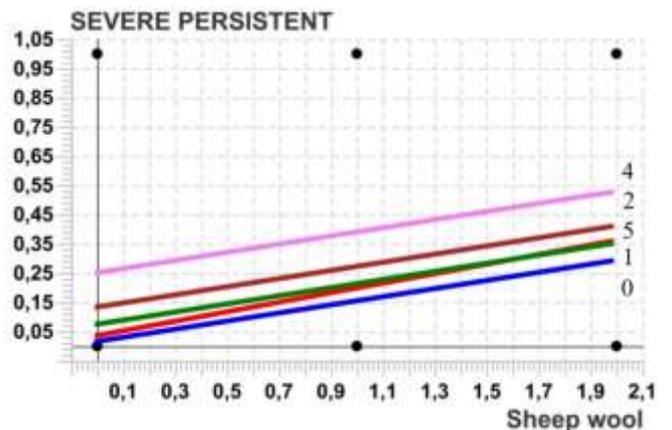


Fig. 4: Two-parameter model  $y = 0,02 + 0,14x_1 + 0,06x_2$ ,  $x_2 = \{0; 1; 2; 4\}$  (Table 2), one-parameter model  $y = 0,0361 + 0,1626x_1$ ,  $x_2 = 5$  (Table: 1)

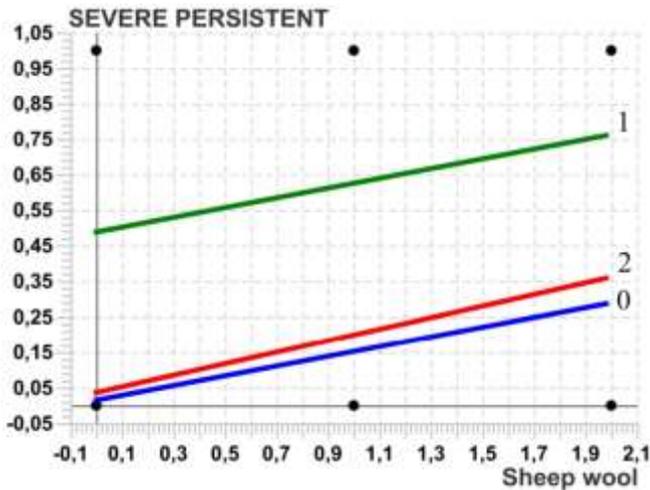


Fig. 5: Two-parameter model  $y = 0,01 + 0,14x_1 + 0,47x_2$ ,

$$x_2 = \{0; 1\} \text{ (Table 2), one-parameter model}$$

$$y = 0,0361 + 0,1626x_1, x_2 = 2 \text{ (Table: 1)}$$

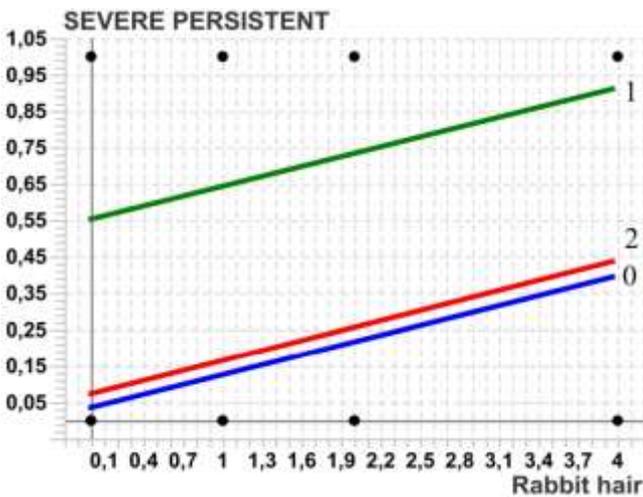


Fig. 6: Two-parameter model  $y = 0,04 + 0,09x_1 + 0,52x_2$ ,

$$x_2 = \{0; 1\} \text{ (Table 2), one-parameter model}$$

$$y = 0,0735 + 0,0916x_1, x_2 = 2 \text{ (Table: 1)}$$

**The approximate two-parameter linear model**

It was discussed above that the correlation coefficient  $r_{x_m x_v}$  between the model regressors is small compared to 1.0:  $r_{x_m x_v} \ll 1$ .

When choosing the factors of the model determined by condition (4), it is also assumed that

$$r_{x_m x_v} < r_{y x_v} \quad r_{x_m x_v} < r_{y x_m}$$

Taking this into account, the expression for the coefficients  $\beta_m$  and  $\beta_v$  (14) can be represented as

$$\beta_m = \frac{r_{y x_m} - r_{y x_v} r_{x_m x_v}}{1 - (r_{x_m x_v})^2} \approx (r_{y x_m} - r_{y x_v} r_{x_m x_v}) \left( 1 + (r_{x_m x_v})^2 \right) \approx r_{y x_m} - r_{y x_v} r_{x_m x_v} \approx r_{y x_m} + 0(r_{x_m x_v}), \tag{17}$$

$$\beta_v = \frac{r_{y x_v} - r_{y x_m} r_{x_m x_v}}{1 - (r_{x_m x_v})^2} \approx (r_{y x_m} - r_{y x_m} r_{x_m x_v}) \left( 1 + (r_{x_m x_v})^2 \right) \approx r_{y x_m} - r_{y x_m} r_{x_m x_v} \approx r_{y x_v} + 0(r_{x_m x_v}). \tag{18}$$

Substituting the obtained expressions for the coefficients into equation (11), let's obtain an approximate two-parameter model for assessing the severity

$$\eta = r_{y x_m} \cdot \xi_m + r_{y x_v} \cdot \xi_v + 0(r_{x_m x_v}). \tag{19}$$

The approximate two-parameter model (19) is a superposition of two one-parameter models (7). The error in calculating the coefficients  $\beta_m$  and  $\beta_v$  (14) is determined by the magnitude of the

correlation between the regressors of the model  $0(r_{x_m x_v})$ .

**RESULTS AND DISCUSSION**

One of significant prognostic factors of severe BA is infantile sensitization and sensitization to a big number of allergens [24]. Numerous studies of allergens, such as house dust mites, mold and cat hair, have proved their role in asthma triggering mechanism in children [25, 26]. The atopic outcome risk is the highest in childhood, while it also increases among grown-ups. The result of allergen affecting significantly depends on the allergen dose and type, its exposure time and child's frailty [27, 29]. Asthma progress is more frequently observed in children suffering from atopic dermatitis or allergic rhinitis [30-32]. The study of Corren J. has proved that treatment of allergic rhinitis decreases the risk of severe bronchial asthma [33].

One-parameter linear regression models are the most commonly used in bronchial asthma severity analyzing during preliminary experimental data processing. Their use can be explained by simplicity of the model building. One-parameter linear model reveals dependence of one variable (interpretable variable) on another variable (regressor) with a linear connection function. One-parameter linear regression coefficient  $b_m$  (5) is an important model criterion. This coefficient defines the rate of a dependent variable change on the given factor (regressor) with fixed values of the rest of the factors; it is proportional to the correlation coefficient between the observed value of  $Y$  and the regressor of  $X_m$  (7),  $m = 1..M$ . One-parameter linear regression model allows setting up qualitative characteristics at the preliminary stage of analysis. However, most often during a preliminary study, a seeker has to get an approximate estimation of an interpretable variable dependence on several factors in order to specify qualitative dependences among the model factors. Models of multiple regression are used to specify the analysis. However, even a building of two- or three-parameter linear regression models requires either massive calculations or specialized software. This is due to the fact that the total amount of two-parameter models is proportional to  $\sim M^2$ , and the total amount of three-parameter models is proportional to  $\sim M^3$ . The essential feature of bronchial asthma severity analysis is connected with the fact that the observed value depends on a large amount of factors  $M \sim 100$ . Correlation connection between the observed value and the regressor is weak for the most of regressors and the connection between regressors themselves is almost absent (Table 3)[19]. This is exactly what allows us to simplify a building of approximate two- or three-parameter linear regression models significantly. Whereby, as illustrated above, an error appearing when a proximate regression model is replaced with an approximate one can be defined as a value which is proportional to the correlation coefficient of the model regressors  $0(r_{x_m x_v})$ .

A comparative analysis of approximate model determined by coefficients (14) and an approximate model determined by coefficients (17), (18) for regressors with maximum values of the correlation coefficient of  $r_{y x_m}$  (Table 3) is presented in Table 5.

Table 5 shows the form of an approximate and proximate two-parameter model as well as error estimation for an approximate model.

**Table: 5. Estimation of an approximate linear regression model**

dimensionless pairwise regression model for $Z_1$	dimensionless pairwise regression model for $Z_2$	two-parameter dimensionless model	approximate two-parameter dimensionless model $g_{2appx} = g_{11} + g_{12}$	approximate model error $\Delta g = g_2 - g_{2new}$
Allergic rhinitis $g_{11} = 0,31z_1$	Sheep wool $g_{12} = 0,3245z_2$	$g_2 = 0,32z_1 + 0,34z_2$	$g_2 = 0,31z_1 + 0,317z_2$	$\Delta g = 0,01z_1 + 0,015z_2$
	Rabbit hair $g_{12} = 0,2394z_2$	$g_2 = 0,28z_1 + 0,20z_2$	$g_2 = 0,31z_1 + 0,2394z_2$	$\Delta g = -0,03z_1 + 0,039z_2$
Sheep wool $g_{11} = 0,3245z_2$	Bronchial asthma in relatives of second generation $g_{12} = 0,3024z_2$	$g_2 = 0,27z_1 + 0,39z_2$	$g_2 = 0,31z_1 + 0,3024z_2$	$\Delta g = -0,04z_1 + 0,087z_2$
	Rabbit hair $g_{12} = 0,2394z_2$	$g_2 = 0,28z_1 + 0,15z_2$	$g_2 = 0,324z_1 + 0,239z_2$	$\Delta g = -0,04z_1 - 0,079z_2$
Rabbit hair $g_{11} = 0,2394z_2$	Bronchial asthma in relatives of second generation $g_{12} = 0,3024z_2$	$g_2 = 0,27z_1 + 0,38z_2$	$g_2 = 0,324z_1 + 0,302z_2$	$\Delta g = -0,05z_1 + 0,078z_2$
	Bronchial asthma in relatives of second generation $g_{12} = 0,3024z_2$	$g_2 = 0,24z_1 + 0,41z_2$	$g_2 = 0,24z_1 + 0,3024z_2$	$\Delta g = 0,1016z_2$

The results of the comparative analysis clearly demonstrate that replacing a proximate model with an approximate one leads to an error of 3% to 10%, which is a fairly good result. Two-parameter

models in a dimensionless and a dimensional form for the studied regressors are shown in Table 6.

**Table: 6 Two-parameter models**

N <sup>o</sup>	regressor $Z_1$	regressor $Z_2$	two-parameter dimensionless model	two-parameter model
1	Allergic rhinitis	Sheep wool	$g_2 = 0,32z_1 + 0,34z_2$	$y = -0,07 + 0,21x_1 + 0,17x_2$
2	Allergic rhinitis	Rabbit hair	$g_2 = 0,28z_1 + 0,20z_2$	$y = -0,01 + 0,18x_1 + 0,08x_2$
3	Allergic rhinitis	Bronchial asthma in relatives of second generation	$g_2 = 0,27z_1 + 0,39z_2$	$y = 0,18x_1 + 0,49x_2$
4	Sheepwool	Rabbit hair	$g_2 = 0,28z_1 + 0,15z_2$	$y = 0,02 + 0,14x_1 + 0,06x_2$
5	Sheepwool	Bronchial asthma in relatives of second generation	$g_2 = 0,27z_1 + 0,38z_2$	$y = 0,01 + 0,14x_1 + 0,47x_2$
6	Rabbit hair	Bronchial asthma in relatives of second generation	$g_2 = 0,24z_1 + 0,41z_2$	$y = 0,04 + 0,09x_1 + 0,52x_2$

One-parameter linear regression models that were used to build an approximate two-parameter model are presented in Table 7.

As well as in the case of two-parameter models, one-parameter regression models are given both in a dimensionless form and in a dimensional form. The models are built for the factors defined in Table 3.

It should be mentioned that for a limiting case when there is no connection between model regressors  $r_{x_m x_v} = 0$ , the expression for

an approximate model satisfies the expression defining the value of interpretable quantity for a proximate model completely (18). If a model contains regressors, then a high value correlation coefficient between them, replacing of proximate regression models with approximate ones, will lead to significant errors. That's why an estimation of correlation coefficients between model regressors is required before immediate application of the model-building method. Choice of the factors to be represented as model regressors has to follow the criterion (1).

Table 7. One-parameter model

Nº	regressor $Z_1$	Dimensionless one-parameter model	one-parameter model
1	Allergic rhinitis	$g_{11} = 0,31z_1$	$y = 0,025 + 0,2x_1$
2	Sheep wool	$g_{11} = 0,3245z_1$	$y = 0,0361 + 0,1626x_1$
3	Rabbit hair	$g_{11} = 0,2394z_1$	$y = 0,0735 + 0,0916x_1$
4	Bronchial asthma in relatives of second generation	$g_{11} = 0,3024z_1$	$y = 0,0863 + 0,5193x_1$

## CONCLUSIONS

One-parameter linear regression models can be successfully used to build estimated two-parameter models that can be recommended for diagnosis of bronchial asthma severity. The suggested method of estimated two-parameter models has satisfactory accuracy allowing to use the suggested class of models to determine connections between the observed value and the factors under study.

The use of approximate models allows to simplify the analysis of experimental data defining severity of bronchial asthma during preliminary data processing. Approximate models help to hasten the process of the set of factors of regression model determination. Significant hastening is caused by the fact that one-parameter models can be replaced with two-parameter regression models during a preliminary stage of analyzing. Such a replacement for studies where an observed value depends on a large amount of factors helps to increase the data analysis accuracy. The accuracy of models replacement is higher, the smaller is the coefficient between the model regressors.

The suggested method of the approximate two-parameter linear regression model can be used for preliminary analyzing of different medical research where observed value depends on a large amount of loosely connected factors. In this case the level of complexity of two-parameter linear regression model building corresponds to the level of complexity of one-parameter linear regression model building.

Development of estimated three- and four-parameter models building for diagnosis of bronchial asthma severity is the perspective of further studies.

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