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Yurii O. Bezsmertnyi*[a], Viktor I. Shevchuk[a], Iryna V. Kurylenko[a], Halyna V. Bezsmertna[a], Sergii M. Zlepko[b], Tetiana I. Kozlovska[b], Olena Yu. Teplova[c], Zbigniew Omiotek[d], Aigul Syzdykpayeva[e]

[a]Scientific Research Institute of Invalid Rehabilitation on the base of Vinnitsa Pirogov National Medical University, Vinnytsia, Ukraine; [b]Vinnitsa National Technical University, Vinnytsia, Ukraine; [c]Vinnytsia State Pedagogical University named after Mikhail Kotsyubinsky, Vinnytsia, Ukraine; [d]Lublin University of Technology, Lublin, Poland; [e]Sarsen Amanzholov East Kazakhstan State University, Ust-Kamenogorsk, Kazakhstan

ABSTRACT

On the basis of mathematical modeling, prognostic measures are identified in the individual rehabilitation program (IRP), which influence on the effectiveness of the rehabilitation process and reduce the limitations in disabled individuals with cardiovascular diseases. According to a multivariate stepwise discriminant analysis, the main rehabilitation measures that increase the effectiveness of rehabilitation in persons with disabilities due to cardiovascular diseases are: "restorative therapy", "medical observation", "counseling on physical rehabilitation", "therapeutic physical education", "examination potential professional abilities", "professional orientation", "rational employment" and "adequacy of the profession and specialty recommended in IRP". Taking into account these measures and their implementation will significantly increase the effectiveness of rehabilitation of a person with disabilities with cardiovascular pathology.

Key words: prognostic model, individual rehabilitation program, rehabilitation, disabilities cardiovascular diseases

1. INTRODUCTION

In recent decades cardiovascular diseases continue to keep the leading positions among the world population in causing disability. Thus, in Europe, more than 64 million people with cardiovascular pathology have sustained functional limitations, accounting for 23% of the total number of disabled individuals[1,2,15]. The reason of this trend is high prevalence of cardiovascular diseases on the one hand, and inadequate and ineffective rehabilitation measures, on the other[1]. Therefore, improvement of rehabilitation system in individuals with cardiovascular pathology has become one of the priority tasks both in Ukraine and worldwide. Rehabilitation service of disabled persons is regulated by unified individual rehabilitation program (IRP), its main function is the provision of comprehensive rehabilitation of a particular individual in order to eliminate the existing limitations in performance of daily life activities, or prevent their development and progression[4,5]. Most scientific papers deal with the study efficacy of separate rehabilitation methods, focusing on medical and physical aspects[6,7], although integrated approach is required to achieve target result in the process of life activity restoration[8-10].

2. OBJECT AND METHODS OF STUDY

The purpose of the study was to determine prognostically significant measures, included in individual rehabilitation program, which would influence the efficacy of rehabilitation process and decrease life activity limitations in disabled individuals with cardiovascular diseases by mathematical modeling method.

*bezsmertnyiyurii@gmail.com

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IRP of 53412 disabled individuals from 22 regions of Ukraine with circulatory diseases were retrospectively studied (ICD-10 codes: I00-99, except I60-I69, I71-I83).The ratio percentage of patients was the following: by age – 13.8% – young, 71.5% – middle-aged, 14.7% – elderly; by gender – 38.0% – females, 62.0% – males. According to IRP data, 100.0% of disabled persons required medical rehabilitation measures, professional rehabilitation was required by 33.8%, vocational – by 53.8%, physical – by 73.4%, psychological and pedagogical adjustment – by 60.4%, social and personal – by 2.5%, rehabilitation equipment – by 15.4%, medical products – by 5.9% of disabled individuals.

The study was conducted by 61 parameters – types of rehabilitation services, formulated in the valid Form of Individual Rehabilitation Program (IRP) of a disabled person. Measures of medical, psychological and pedagogical, physical, professional, vocational, physical culture and sport, social and household rehabilitation, provision with rehabilitation equipment and medical products were analyzed[11-13].

Three-year monitoring of corresponding parameters (2012–2014) were performed. The parameters were evaluated by calculating Wilkes' Lambda variables, analyzing the received system of classification equations and the model validity. The variable "life activity restoration" of a disabled person within 1 year of compiling IRP was used as the endpoint. Grading of the variable "life activity restoration" was done according to the following classification: "complete restoration of life activity", "partial restoration of life activity", "no restoration of life activity", "increased limitation in performance of life activity".

Software package SCM Maple 15 was used in statistical processing of numerical data. In order to identify the priority parameters, having predictive value in achieving the endpoint and creation of predictive model, a multivariate Fisher's linear discriminant analysis was used.

General model of multivariate regression is (1):

$$Y = a_0 + a_1 x_1 + a_2 x_2 + \mathrm{L} + a_{60} x_{60} + a_{61} x_{61}, \quad (1)$$

where: y – an indicator of innovation effectiveness; $x_1, x_2, x_3, \ldots, x_{60}, x_{61}$ – factors influencing the performance indicator; a_0 – constant index, independent of impact factors; $a_1, a_2, a_3, \ldots, a_{60}, a_{61}$ – multivariate regression coefficients. Using the data obtained, mathematical modeling was carried out to identify the priority measures of medical and social rehabilitation, which would improve the efficiency of IRP in disabled individuals. Methods used: statistical, analytical, meta-analysis of IRP data, mathematical modeling by multivariate Fisher's linear discriminant analysis.

3. RESULTS OF THE RESEARCH AND DISCUSSION

At the first stage of the study, estimated regression coefficient vector was determined, and linear regression model was created regarding the indicator of life activity restoration in disabled patients with circulatory diseases. According to the least squares method, the vector $Y(x)$ was obtained by the formula (2):

$$Y(x) = \left(X^T X\right)^{-1} \left(X^T Y\right), \quad (2)$$

where: matrix X – initial input data; matrix Y – the result of life activity limitation. Estimated regression coefficient vector:

$$Y(x) = \begin{pmatrix} \begin{bmatrix} 0.05 \\ 4.95 \\ -1.78 \\ -0.03 \\ -2.18 \\ 0 \\ 0 \\ -0.72 \\ 3.68 \\ -3.9 \\ -0.3 \end{bmatrix} & \begin{bmatrix} -0 \\ -0.07 \\ -0.03 \\ -0.04 \\ -0 \\ 4.32 \\ 0 \\ 0.07 \\ -0.52 \\ 5.12 \\ 4.96 \end{bmatrix} & \begin{bmatrix} 6.13 \\ -0.49 \\ 0.11 \\ 0.3 \\ -2.3 \\ 2.01 \\ 5.84 \\ -0.01 \\ 0.04 \\ 0.05 \\ 0.06 \end{bmatrix} & \begin{bmatrix} -0 \\ -0.58 \\ 0 \\ 0.6 \\ -1.25 \\ -0.06 \\ 1.48 \\ 0.01 \\ -0.01 \\ -0.01 \\ -0.01 \end{bmatrix} & \begin{bmatrix} 0 \\ 0.04 \\ 0 \\ -0.07 \\ 0 \\ 0 \\ 0 \\ -0.07 \\ -0.98 \\ 0.04 \\ 0.01 \end{bmatrix} & \begin{bmatrix} 0 \\ -0.05 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \end{pmatrix}. \quad (3)$$

Correspondingly, linear regression model for life activity restoration index in disabled individuals with circulatory system disorders is the following:

$$y = 0.05 + 4.95x_1 - 1.78x_2 - 0.03x_3 - 2.18x_4 + 0x_5 + 0x_6 - 0.72x_7 + 3.68x_8 - 3.9x_9 - 0.3x_{10} - 0x_{11} - \\ -0.07x_{12} - 0.03x_{13} - 0.04x_{14} - 0x_{15} + 4.32x_{16} + 0x_{17} + 0.07x_{18} - 0.52x_{19} + 5.12x_{20} + 4.96x_{21} + \\ +6.13x_{22} - 0.49x_{23} + 0.11x_{24} + 0.3x_{25} - 2.3x_{26} + 2.01x_{27} + 5.84x_{28} - 0.01x_{29} + 0.04x_{30} + 0.05x_{31} + \\ +0.06x_{32} - 0x_{33} - 0.58x_{34} - 0x_{35} + 0.6x_{36} - 1.25x_{37} - 0.06x_{38} + 1.48x_{39} + 0.01x_{40} - 0.01x_{41} - \\ -0.01x_{42} - 0.01x_{43} - 0x_{44} + 0.04x_{45} + 0x_{46} - 0.07x_{47} - 0x_{48} - 0x_{49} + 0x_{50} - 0.07x_{51} - 0.98x_{52} + \\ +0.04x_{53} + 0.01x_{54} + 0x_{55} - 0.05x_{56} - 0x_{57} - 0x_{58} + 0x_{59} - 0x_{60} + 0x_{61} \quad , \tag{4}$$

where:

	1. Medical rehabilitation
x_1	Restorative therapy
x_2	Preventive measures
x_3	Reconstructive surgery
x_4	Health resort treatment
x_5	Psychiatric support
x_6	Hearing prosthetics
x_7	Cochlear implantation
x_8	Medical screening
	2. Psychological and pedagogical rehabilitation
x_9	Counseling services
x_{10}	Psychological and pedagogical diagnosis
x_{11}	Psychological and pedagogical nursing
x_{12}	Psychological and pedagogical correction
x_{13}	Educational services
x_{14}	Collective form of training, including mainstreaming and inclusive learning
x_{15}	Online training, external studies
	3. Physical rehabilitation
x_{16}	Counseling services
x_{17}	Ergotherapy
x_{18}	Kinesitherapy
x_{19}	Massage therapy
x_{20}	Exercise therapy
	4. Professional rehabilitation
x_{21}	Examination of potential professional abilities
x_{22}	Professional orientation
x_{23}	Professional selection
x_{24}	Vocational training, retraining and advanced studies

x_{25}	Vocational education
	5. Vocational rehabilitation
x_{26}	Creation of workplace and its adaptation in terms of safety and special needs of a disabled person
x_{27}	Rational employment (renewal of work activity of a disabled person in previous or new career)
x_{28}	Types of careers and specialties suitable for health reasons
	6. Physical training and sport rehabilitation
x_{29}	Instruction in physical training skills
x_{30}	Health improvement and rehabilitation in physical culture and sports camps for disabled
x_{31}	Training lessons in physical culture and sport
x	***7. Social and home rehabilitation***
x_{32}	Training of major social skills
x_{33}	Furniture adjustment, installation of equipment for adaptation of living accommodations
x_{34}	Social home nursing
x_{35}	Occupational therapy
	II. Technical and other means of rehabilitation
	1. Means of transport:
x_{36}	Wheelchairs of various types
x_{37}	Sticks
x_{38}	Crutches
x_{39}	Supportive walking aids
x_{40}	Mobile telephones for written communication, faxes and other surd technical aids
x_{41}	Tiflo-radio-tape recorders
x_{42}	Watch
x_{43}	Tactile walking sticks
x_{44}	Supportive house hold appliances
x_{45}	Supportive toilet aids
x_{46}	Supportive aids for rising
x_{47}	Wheel-chairs with sanitary facilities
x_{48}	Training computer programs
x_{49}	Special textbooks, books printed in Braille
x_{50}	Special furniture
x_{51}	Orthopedic products
x_{52}	Orthopedic shoes
x_{53}	Special clothes
x_{54}	Special wheelchairs for exercise in some kinds of sport
x_{55}	Artificial heart valve prostheses, bifurcation vascular prostheses, linear vascular prostheses, conduits, valveimplanted shunt systems

x_{56}	Provision with pacemakers
x_{57}	Oxygenators, coronography systems, coronarys tenting systems, aortocoronary bypass grafting systems
x_{58}	Urine-collecting bags
x_{59}	Ostomy bags
x_{60}	Hearing aids
x_{61}	Canes

Using multivariate regression analysis, rehabilitation methods having positive influence on the process of restoration/improvement of daily living activities in disabled patients with circulatory diseases were determined. Among them: medical rehabilitation measures – "restorative therapy" and "medical screening"; physical rehabilitation measures – "counseling services" and "exercise therapy"; professional rehabilitation measures – "examination of potential professional abilities" and "vocational education"; vocational rehabilitation – "rational employment" and "occupation or specialty recommended in IRP". Although such rehabilitation services as "kinesitherapy", "vocational training, retraining and advanced studies", "vocational education", "health improvement and rehabilitation in physical culture and sports camps for disabled", "training lessons in physical culture and sport", "training of major social skills", "wheelchairs of various types", "mobile telephones for written communication, faxes and other surd technical aids", "supportive toilet aids", "special clothes", "special wheelchairs for exercise in some kinds of sport" had positive prognostic influence on rehabilitation efficacy, they were statistically in significant according to the data obtained.

At the same time, some rehabilitation measures were not found to have prognostic value in the process of restoration or improvement of life activity. The most representative of them were "preventive measures" and "health resort treatment". Those types of rehabilitation services were thought to be either uncommonly used ("health resort treatment" in disabled patients with cardiovascular pathology in particular), or control over compliance with "preventive measures" was absent or neglected by the patients themselves[3,14].

Thus, the study results enabled to identify the priority rehabilitation measures. They are the following: "restorative therapy", "medical screening"; "counseling in physical rehabilitation", "exercise therapy", "examination of potential professional abilities", "vocational education";"rational employment" and "occupation or specialty recommended in IRP". Their targeted implementation will positively influence the ultimate outcome: restoration or improvement of vital activity of a disabled individual[16-18, 21-23].

During the next stage of the study probable prognosis of efficacy of recommended rehabilitation measures in different regions of Ukraine was determined (Table 1). The data obtained were analyzed by their statistical significance *Y/Y(x),* where:

a) 7000-10000 – probability of complete and partial life activity restoration – 62% and 38%, respectively;
b) 4000-7000 – probability of partial life activity restoration – 57%, no restoration – 43%;
c) 0-4000 – probability of no life activity restoration – 52%, worsening – 48%.

According to the data of Table1, the structure of medical and social rehabilitation of disabled individuals, available in Ukraine at present, predicts only "partial restoration" of life activity limitations in the Western region. In other regions of the country "no restoration" of some aspects of life activities is probable in 52% of disabled persons, "increase in life activity limitations" – in 48% of patients. Such data predict either "stability" or "increase" in the severity of disability, which emphasizes the relevance of improving the existing system of rehabilitation of the disabled patients with circulatory system pathology[19,20]. Actual and estimated values of the model are represented as curves in Fig. 1.

Table 1. Prognosis of life activity limitation.

Region	Life activity limitation, indices	Prognostic value of life activity limitation according to created model
	Y	*Y(x)*
Centre	3327.88	3495.67
West	4110.82	4273.20
East	2359.84	2253.91
North	1676.32	1610.30
South	906.60	755.50

In order to check the significance of the equation and its coefficients, to study absolute and relative approximation errors, statistical analysis of the regression equation obtained was performed. For unbiased estimation of variance, the following calculations were done: Unbiased error ε = Y-Y (x) = Y-X · s. The data received are presented in Table 2.

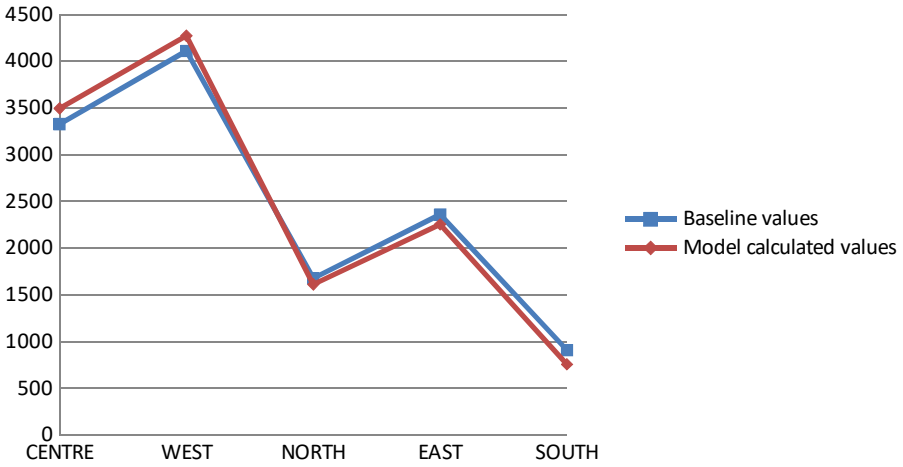

Figure 1. Predicted efficacy of restoration of life activity limitations.

Table 2. Results of calculations of intermediate parameters to check Fisher's F-criterion.

Y	Y(x)	ε = Y-Y(x)	ε^2	$(Y-Y_m)^2$	| ε/Y|
3327.88	3495.67	-167.79	28153.48	725205.53	0.050419
4110.82	4273.20	-162.38	26367.26	2671688.32	0.039501
2359.84	2253.91	105.93	11221.16	13560.60	0.044889
1676.32	1610.30	66.02	4358.64	639952.00	0.039384
906.60	755.50	151.10	22831.21	2463926.70	0.166667
			92931.76	6514333.15	0.340859

Mean approximation error is:

$$A = \frac{\sum \left| \frac{\varepsilon}{Y} \right|}{n} 100\% = \frac{0.340859}{5} 100\% = 6.82\% \cdot \tag{5}$$

Thus, the error of the model created was 6.82%. Estimation of dispersion:

$$s_e^2 = \left(Y - X \cdot Y(x)\right)^T \cdot \left(Y - X \cdot Y(x)\right) = 92931.76. \tag{6}$$

Unbiased estimation of variance:

$$s^2 = \left| \frac{s_e^2}{n-m-1} \right| = 1548.86 \cdot \tag{7}$$

Estimation of standard error of the mean (*standard error in Y assessment*):

$$S = \sqrt{s^2} = 39.36. \tag{8}$$

The degree of combined influence of factors on the end point was evaluated by multiple correlation index, its value being 0-1. Therefore, R can be used to interpret the direction of linear correlation. The more closely actual y_i values were located at regression line, the less residual variance was and, hence, the greater value of $R_y(x_1, \ldots , x_m)$.

When the value of R approximated 1, the regression equation reflected actual data better, and the parameters had stronger influence on the result. In the value of R approximating 0, the regression equation reflected actual data badly, and the parameters had weak influence on the result:

$$R = \sqrt{1 - \frac{s_e^2}{\sum \left(y - y_{cp} \right)^2}} = \sqrt{1 - \frac{92931.76}{6514333.15}} = 0.9857 \cdot \tag{9}$$

Strong relationship between factors Y and X was found. Significance of multiple regression equation was evaluated by checking the hypothesis stating that determination coefficient, calculated by population data, is equal to zero. Fisher's F-criterion was used for this purpose:

$$R^2 = 0.9716, \tag{10}$$

$$F = \frac{R^2}{1-R^2} \frac{n-m-1}{m} = \frac{0.9716}{1-0.9716} \frac{61-5-1}{5} = 376.32, \tag{11}$$

$$F_{кр} = 2.37. \tag{12}$$

Since the actual value of $F>F_{kp}$, determination coefficient is statistically significant, hence the regression equation obtained is statistically valid. This is indicative of the model validity which can be used in prognosis and further analysis.

4. CONCLUSIONS

1. The structure of medical and social rehabilitation of disabled with cardiovascular pathology, available in Ukraine at present, predicts mostly "no restoration" or "increase" in life activity limitations emphasizing the need for improving IRP.
2. Prognosis of the end point ("restoration of vital activity") in disabled individuals with cardiovascular pathology should be based on multivariate statistical model considering 61 major parameters in compiling IRP.
3. According to multivariate stepwise discriminant analysis, major rehabilitation measures increasing rehabilitation efficacy in disabled individuals with cardiovascular diseases are the following: "restorative therapy", "medical screening"; "counseling in physical rehabilitation", "exercise therapy", "examination of potential professional abilities", "vocational education"; "rational employment" and "occupation or specialty recommended in IRP". Their integrated implementation will provide successful rehabilitation of disabled individuals with cardiovascular diseases.

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