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MATHEMATICAL PREDICTION OF THE NUMBER OF OFFICIALLY REGISTERED HIV-POSITIVE PEOPLE IN THE REGION AS A TOOL FOR PLANNING EXPENSES IN DIFFERENT DIRECTIONS OF EPIDEMIC COUNTERACTION

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Purpose – *to conduct prediction of the expenses for treatment, care and support of PLWH in the period of the current target social program of HIV/AIDS counteraction (2017–2018) in Transcarpathian region with the use the technology of mathematical prediction of the number of registered HIV-positive people in the region.*

Methods *of study: statistical, retrospective epidemiological, of mathematical prediction, information-and-analytical, of systemic analysis.*

Results. The results forecast, the expected number of new HIV infections in 2016 is 87–88 individuals in 2017 and 2018 – 89–90 and 90–91 people person respectively. The number of officially registered HIV-positive people by the end of 2016 forecast will be 469–470 people, and at the end of the period of the Programme Against HIV/AIDS (2018) – 584–585 people. Estimated costs for direction HIV treatment in 2018 will increase compared to 2014 by 3.5 times (in US dollars), and the cost of care and support in 2018 will be lower than costs in 2014 by 17.6%.

Conclusions. Mathematical prediction applying synthesized scheme predicting the number of officially registered HIV-positive people at the regional level can be used as an instrument for planning expenses to provide the directions of treatment and care and support for HIV-positive people in subsequent years of the implementation of these measures.

Key words: mathematical prediction, HIV-positive people, costs of countering HIV/AIDS.

INTRODUCTION

State and national programs in Ukraine aimed at HIV/AIDS epidemic counteraction are, in their essence, there programs of organizing the provision of different services (medical, social, psychological, etc.) for target groups of population, directed to solving the main goal and tasks of these programs [5]. Basic share among the measures of implementing such programs constitute the areas of medical services (preventive, diagnostic and therapeutic) for the representatives of different groups of population, including persons registered in groups at risk concerning HIV and people living with HIV (PLWH) [12]. When planning provision of services included in the program, the key point is the availability of information on the expected number of the consumers of these services on the territory of the program implementation for the period of its implementation. The measures of the program have clear numerical indices of their implementation, in particular the indices of covering the representatives of target groups of population with special services and activities [10]. Thus, all tasks and measures for the implementation of the current State target social program aimed at HIV/AIDS counteraction for the years 2014–2018 are put together in five groups: organizational objectives and measures; preventive tasks and activities; laboratory diagnostics and assurance of the quality of studies; treatment of patients with HIV/AIDS and also care and support. When planning activities on prevention of HIV-infection among the representatives of different groups of population official data of the State statistics are taken or, in case of developing the activities for groups at risk, the rating data [7] are used, which are determined at the national level based on the results of the special epidemiological and behavioral studies [9]. Group of measures in the program that are aimed at providing services to PLWH (the treatment of patients with HIV/AIDS, care and support) requires the data on prediction of the number of representatives of this group for the period of the program implementation. At the national level to assess the number of PLWH used the program Spectrum/EPP 4.47 is used [15]. However, at the regional level the application of this software is limited. Therefore, the introduction of techniques of quantitative forecasting of the characteristics and methods of determining the estimated number of groups at risk is limited and is not currently in use. To solve the problem of determining the estimated number of groups at risk at regional level a special information technology was developed [6], but in the case of planning specific activities to provide services of treatment, care and support for PLWH at the level of region, or a specific health care institution, information is need not only about the estimated number of PLWH living in the region, but also about the prognosis of the number of PLWH who are registered in health care institutions on HIV/AIDS counteraction in the region. This is especially important for efficient planning of the necessary financial resources and projected expenses for specific activities of the program for the annual stage of its implementation.

Purpose of study – to conduct prediction of the expenses for treatment, care and support of PLWH in the period of the current target social program of HIV/AIDS counteraction (2017–2018) in Transcarpathian region with the use the technology of mathematical prediction of the number of registered PLWH in the region.

MATERIALS AND METHODS

The following methods were used to reach the goal of study: statistical, retrospective epidemiological, of

mathematical prediction, information-and-analytical, of systemic analysis.

The next coming basic quantitative characteristics of officially registered HIV-infected persons in the region:

− new case of HIV-infection in the chosen year;

− new case of AIDS in the chosen year;

− number of HIV-positive persons by the end of the year;

− number of persons sick for AIDS by the end of the year.

Mathematical prediction of the number of officially registered PLWH was carried out with the use of synthesized prognosing scheme [13] on the base of the following methods: method of autoregression, method of least squares with weights, Brown's method (linear and quadratic model), Winters method.

Retrospective analysis of principal quantitative characteristics of officially registered HIV-positive persons in the region in 1987–2015 was conducted for the formation of variation series. The data of State Statistical Report of the Ministry of Health of Ukraine – reporting forms № 2 – AIDS (annual) in Transcarpathian region and official bulletins «HIV-infection in Ukraine» of Ministry of Health of Ukraine [1–3] were taken as the sources of information.

Basic numbers of expenses in 2015 in principal directions of the program (prevention, treatment, care and support and organizational measures), were received by the results of the financial and program monitoring and evaluation of actions of the measures of State target program of HIV/AIDS counteraction for the years 2014–2018 in 2015 results [4] according to the methods defined by the Plan of monitoring and evaluation of the effectiveness of the implementation of State target social program of HIV/AIDS counteraction for the years 2014–2018 [11].

THE RESULTS OF STUDY AND THEIR DISCUSSION

Key index in predicting the expenses per calendar year in the directions «Treatment of HIV-positive and AIDS patients», and «Care and support for PLWH» is the estimated number of recipients of the services in those directions at the end of the calendar year which is the maximal estimated number of persons in the target group.

Therefore, in our study the prediction of the following indices was conducted: index «New cases of HIV-infection in a chosen year», index «New cases of AIDS in a chosen year», index «Number of HIV-positive persons at the end of the year» and index «Number of persons with AIDS at the end of the year».

These indices for the period from 1987 to 2015 in Transcarpathian region are shown in Table 1.

Table 1

The values of principal quantitative characteristics (indices)
of officially registered HIV-infected persons in the region in 1987–2015

Years	New cases of HIV-infection	New cases of AIDS	Number of HIV-positive persons at the end of the year	Number of persons with AIDS at the end of the year
1987–1995	6	1	6	1
1996	10	1	8	2
1997	27	2	35	2
1998	21	2	51	2
1999	20	4	63	4
2000	17	1	77	4
2001	26	3	94	4
2002	12	6	91	4
2003	10	4	77	7
2004	14	22	73	16
2005	36	9	100	23
2006	22	6	109	18
2007	43	3	136	16
2008	42	5	154	17
2009	50	5	185	16
2010	62	3	221	16
2011	63	10	251	22
2012	82	32	288	40
2013	81	35	322	57
2014	83	38	370	87
2015	71	52	421	124

As it can be seen from Table 1, all the indices for the analyzed period tend to vary due to a number of reasons, among which the main is that the data on only officially registered PLWH are considered. Thus, in particular the index «New cases of HIV infection» each year depends on the level of HIV testing coverage, the level of recording of new HIV-infection cases etc.

Indices «Number of HIV-positive people at the end of the year» and «Number of persons with AIDS at the end of the year» are considerably dependent on the level of removal

PLWH from the register in the current year, including those who are removed from the register because of death.

Average quadratic error (Δ) and average relative error (μ) was used in the assessment of the quality of prediction for different steps of prediction (τ) which are correspondingly counted out according to the formulas:

$$\Delta = \sqrt{\frac{\sum_{t=1}^{n}\left(v_t - \tilde{v}_t\right)^2}{n}}, \quad \mu = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{v_t - \tilde{v}_t}{v_t}\right|,$$

where: n – amount of excerption, v_t ($t=1, \ldots, n$) – dynamic line.

The following values of the errors of prediction for individual indices were obtained as a result of the work of prediction schemes for the various steps of prediction.

The results for indices «New cases of AIDS» and «Number of persons with AIDS at the end of the year» were similar.

The values of the prediction errors given in Table 2 testify the efficiency of the method applied. So, the small values of the average quadratic and average relative errors indicate the feasibility of application of prediction scheme [13] for projecting the number of officially registered HIV-positive people in the region.

Thus, the results of projecting of the indices of target group quantitative characteristics with the application of synthesized prediction scheme are presented in Figure 1–4.

Table 2

***The values of the errors of prediction
for individual indices of target group quantitative characteristic***

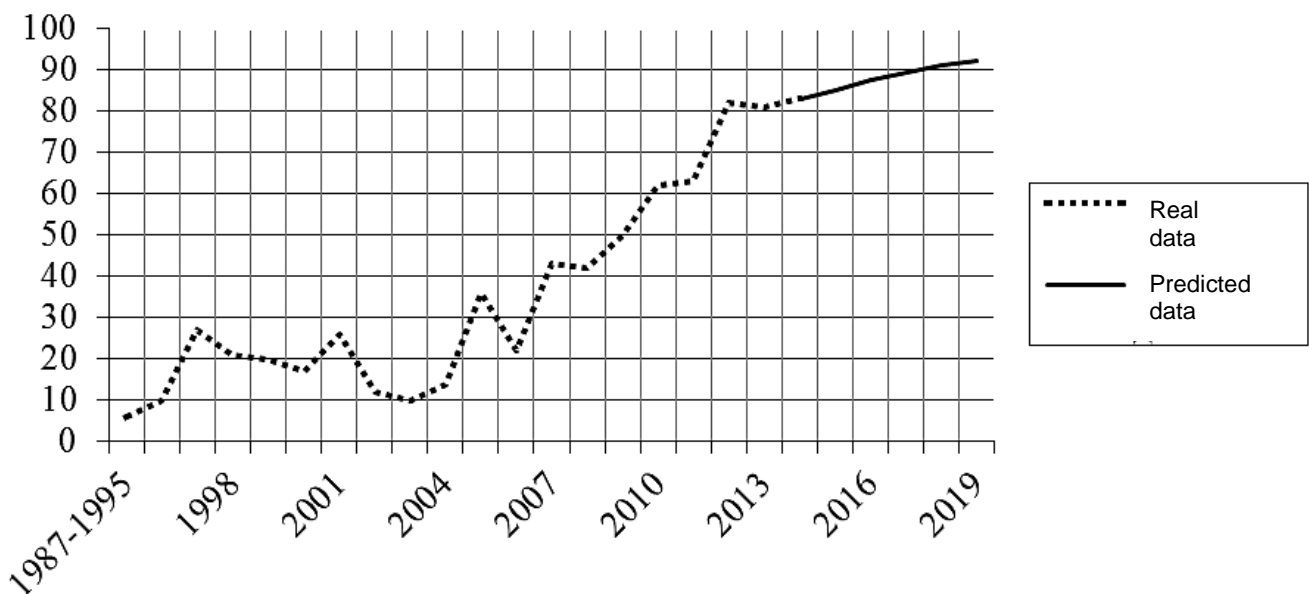| Year	Error	Index «Number of HIV-positive persons at the end of the year»	Index «New cases of HIV-infection»
2015	Δ (τ=1)	2.0878	0.9607
	μ (τ=1)	0.0043	0.008
2017	Δ (τ=3)	3.4319	1.2348
	μ (τ=3)	0.0051	0.0074
2019	Δ (τ=5)	1.4689	0.9617
	μ (τ=5)	0.0024	0.0064

Fig. 1. Results of «New cases of HIV-infection» index prediction
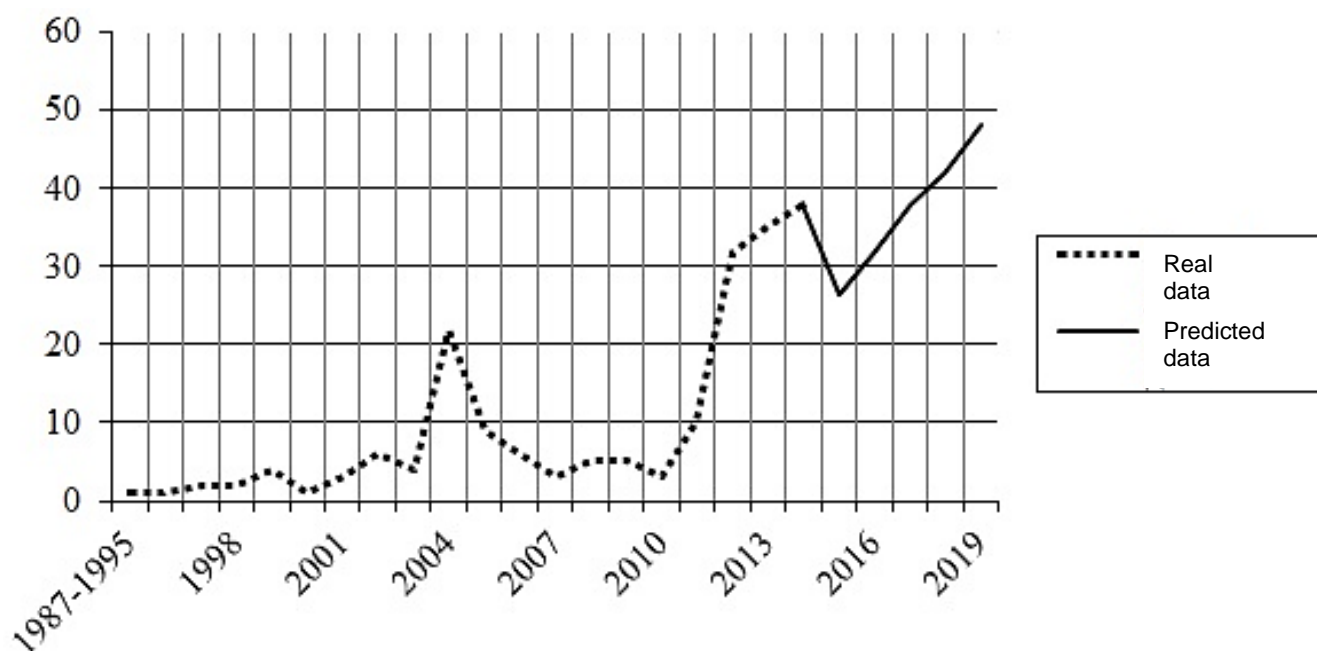
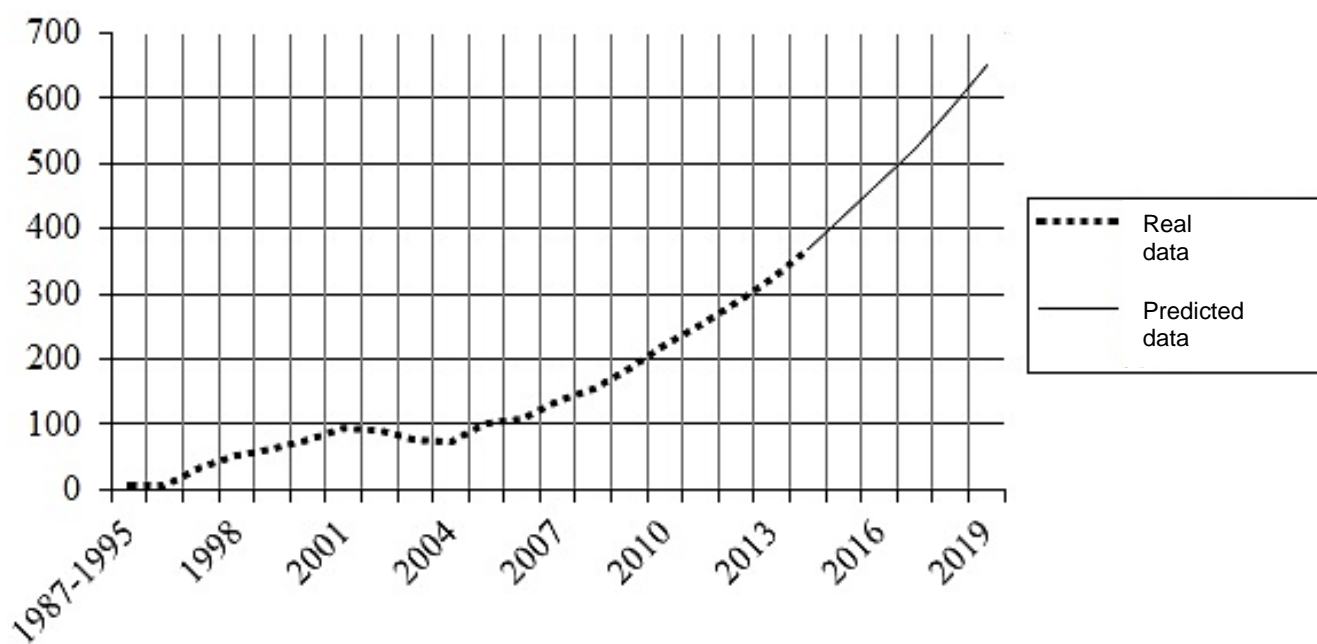***Fig. 2.*** Results of «New cases of AIDS» index prediction

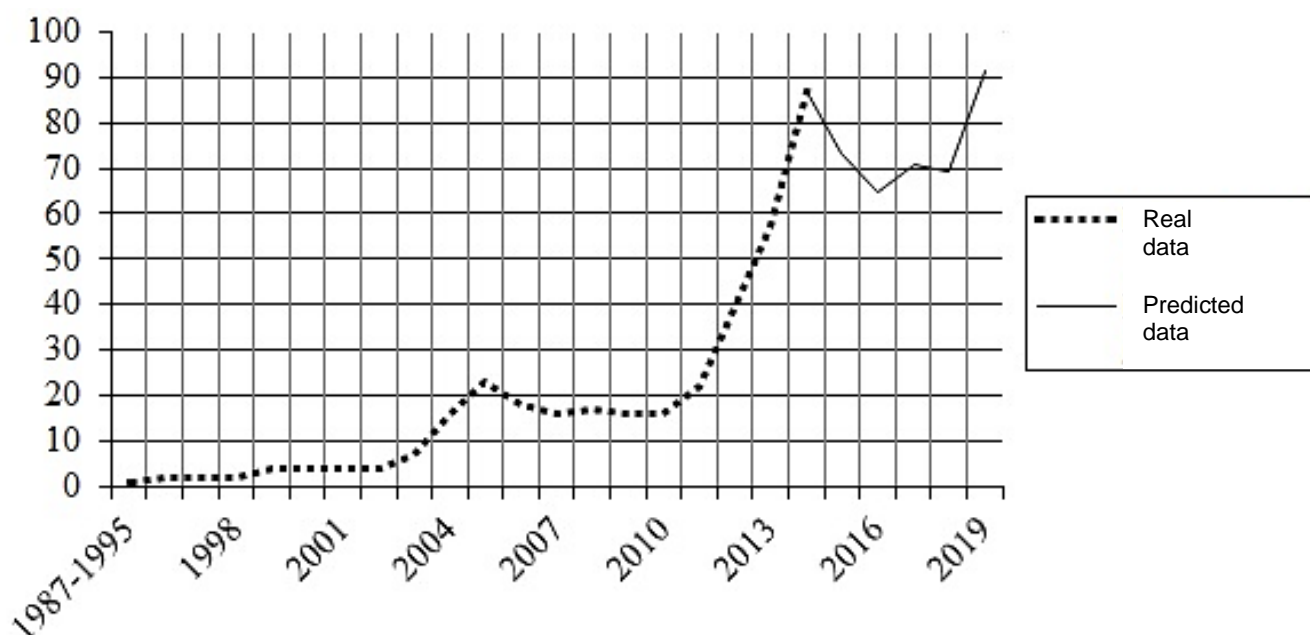***Fig. 3.*** Results of «Number of HIV-infected persons at the end of the year» index prediction

Fig. 4. Results of «Number of persons with AIDS at the end of the year» index prediction

Corresponding calculated predicted values of the indices of quantitative characteristics of officially registered HIV-infected persons in the region for 2016–2018 are presented in table 3.

As it is shown in Table 3, according to the results of the prediction conducted the expected number of new cases of HIV-infection in 2016 is 87–88 persons, in 2017 and 2018 – 89–90 and 90–91 persons respectively. 469–470 HIV-infected persons are expected to be officially registered by the end of 2016 with 584–585 expected by the end of the period of

implementation of the current program for HIV/AIDS counteraction (2018).

The latest evaluation of the expenses for the measures of HIV/AIDS epidemic counteraction in Transcarpathian region was carried out according to plan of the program monitoring and effectiveness assessment [11] by the results of the year 2014 [4]. The results of the allocation of expenses for HIV/AIDS counteraction in principal directions of program activities in 2014 in the region are presented in Figure 5.

Table 3

Calculated predicted values of the indices of quantitative characteristics
of officially registered HIV-infected persons in the region for 2016–2018

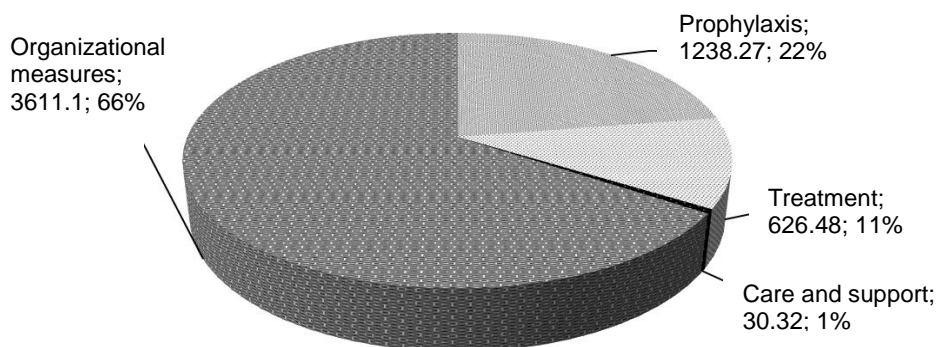| Year	New cases of HIV-infection	New cases of AIDS	Number of HIV-positive persons at the end of the year	Number of persons with AIDS at the end of the year
2016	87.3657	31.7665	469.6764	64.5915
2017	89.3968	37.8206	524.9736	70.9085
2018	90.967	41.9948	584.2279	69.4463

Fig. 5. Allocation of expenses for HIV/AIDS counteraction
in principal directions of program activities in Transcarpathian region in 2014 (thous. UAH)

As it is shown in Figure 5, the main share of expenses (66.0%) in 2014 was directed to the implementation of organizational measures. The share of expenses that were focused on measures of treatment and care and support for PLWH from total amount of expenditure for epidemic counteraction was negligible and composed only 11.0% and 1.0%, respectively.

Naturally, that the increase of the number of PLWH who will be officially registered in the region in 2017–2018 (Table 3) will respectively increase the amount of expenses for the measures aimed at providing medical and non-medical services to PLWH. Therefore, the total expenses for the directions of program activities such as PLWH treatment and care and support for PLWH will rise even while maintaining the existing system of providing these services to the representatives of target group. Introduction in the frames of UN Joint Program on HIV/AIDS (UNAIDS) of UNAIDS strategy 2016–2020 «The acceleration directed to zero-90-90-90» (Fast-Track) [14], which stipulates as one of the objectives that by 2020 90% of PLWH will receive specific treatment, would lead to considerable increase of the expenses for treatment in the following years. Thus, to achieve this goal by 2020 in Ukraine it is necessary to cover another 178 200 PLWH with treatment which is 2.6 times more than the number of people who were receiving antiretroviral therapy (ART) in 2015 (68 455 PLWH (only 31% of the valued number of PLWH)) [3]. According to experts, the number of PLWH receiving treatment should reach by the end of 2018 118 240 persons, that composes 53.75% of the valued number of PLWH at the beginning of 2016 [3]. Taking into consideration that only 126 604 (58.0% of PLWH valued number (220 000) were under medical supervision in Ukraine at the beginning of 2016, to achieve the goals set, the coverage of PLWH with treatment by the end of 2018 should make up at least 90% of the persons under medical supervision. The predicted number of PLWH who should be covered with treatment at the end of 2018 in Transcarpathian region is 525 persons (90% of the valued number of officially registered PLWH by the end of 2018).

146 PLWH which represented 39.5% of persons at clinical accounting were receiving treatment in Transcarpathian region at the end of 2014. The expenses for providing this direction in 2014 amounted to 626.48 thousand UAH (11.0% of all expenses for combating the epidemic) (Fig. 5). As the drugs for antiretroviral therapy are manufactured exclusively abroad it is correctly to calculate the expenses for ensuring treatment equivalently to US dollar. Consequently, the costs of providing treatment for 146 persons in Transcarpathian region in 2014 composed 52.73 thousands of US dollars (according to average annual exchange rate of The National Bank of Ukraine [8]).

Calculation of necessary expenses for providing coverage of 90% of PLWH dispensary group with ART during 2016–2018 in Transcarpathian region in US dollar terms equivalent is presented in Table 4.

As it can be seen from Table 4, the estimated amount of expenditures for the treatment of HIV-positive people in 2018, subject to fulfillment of the plan of PLWH coverage with ART, will increase compared to 2014 year 3.5 times (in US $).

Table 4

Calculation of necessary expenses for providing coverage of 90% of PLWH dispensary group with ART during 2016–2018 in Transcarpathian region (thous. US $)

Year	PLWH dispensary group	PLWH covered with ART	Valued necessary expenses
2016	469–470	422–423	152.34–152.7
2017	524–525	472–473	170.39–170.75
2018	584–585	526–527	189.89–190.25

A slightly different situation we find in assessing the expenses for PLWH care and support. Thus, care and support concerns mostly persons with AIDS. Expenses for providing care and support to 87 PLWH in Transcarpathian region in 2014 amounted to 30.32 thousands UAH (equivalent to 2.55 thousands US $). Calculation of the necessary expenses for providing care and support to patients with AIDS for 2016–2018 in the Transcarpathian region in US dollar equivalent is presented in Table 5.

Table 5

Calculation of the necessary expenses for providing care and support to patients with AIDS for 2016–2018 in the Transcarpathian region (thous. US $)

Year	Clinically accounted patients with AIDS	Valued necessary expenses
2016	64–65	1.92–1.95
2017	70–71	2.10–2.13
2018	69–70	2.07–2.10

As it can be seen from Table 5, projected expenses for care and support of PLWH in 2018 will be 17.6% lower than actual expenses in 2014. It is natural, for with expanded coverage with ART, the number of PLWH with AIDS developed will diminish, that is a sign of treatment effectiveness.

The results of the study presented do not take into account every possible external influence upon the situation that are during such a long period of prediction. At the same time mathematical forecasting the number of officially registered HIV-positive people in the region is an effective instrument of preliminary prognosis of potential expenses for treatment and care and support for PLWH at regional level.

CONCLUSIONS

The results of study conducted give possibility to make conclusions:

Mathematical prediction applying synthesized scheme predicting the number of officially registered PLWH at the regional level can be used as an instrument for planning expenses to provide the directions of treatment and care and support for PLWH in subsequent years of the implementation of these measures.

The evaluation conducted showed that the sum of the expenses for the direction of the treatment of HIV-infected patients in 2018, under the condition of the plan fulfillment the coverage of PLWH from dispensary group with ART will increase in 3.5 times compared to 2014 year (equivalent to US $). At the same time, the predicted amount of expenses for PLWH care and support in 2018 will be 17.6% lower than actual expenses in 2014.

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Математичне прогнозування чисельності офіційно зареєстрованих ВІЛ-інфікованих осіб у регіоні як інструмент планування витрат за напрямками протидії епідемії

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Мета – провести прогнозування витрат на заходи лікування та догляду і підтримки ВІЛ-інфікованих на період дії чинної програми протидії ВІЛ-інфекції/СНІДу (2017–2018 рр.) у Закарпатській області з використанням технології математичного прогнозування чисельності офіційно зареєстрованих ВІЛ-інфікованих у регіоні.

Методи: статистичний, ретроспективний, епідеміологічний, математичного прогнозування, інформаційно-аналітичний та системного аналізу.

Результати. За результатами прогнозування, очікувана кількість нових випадків ВІЛ-інфекції у 2016 р. становить 87–88 осіб, у 2017 та 2018 рр. – 89–90 осіб та 90–91 особа відповідно. Кількість офіційно зареєстрованих ВІЛ-інфікованих осіб на кінець 2016 р. прогнозовано становитиме 469–470 осіб, а на кінець періоду реалізації програми протидії епідемії ВІЛ-інфекції/СНІДу (2018 р.) – 584–585 осіб. Прогнозована сума затрат на напрямок лікування ВІЛ-інфікованих у 2018 р. зросте порівняно з 2014 р. у 3,5 разу (у доларах США), а витрати на догляд і підтримку у 2018 р. будуть менші за витрати у 2014 р. на 17,6%.

Висновки. Математичне прогнозування чисельності офіційно зареєстрованих ВІЛ-інфікованих на регіональному рівні може використовуватися як інструмент планування витрат на забезпечення їх лікування та догляду і підтримки.

КЛЮЧОВІ СЛОВА: математичне прогнозування, ВІЛ-інфіковані, витрати на протидію ВІЛ/СНІДу.

Математическое прогнозирование численности официально зарегистрированных ВИЧ-инфицированных лиц в регионе как инструмент планирования затрат по направлениям противодействия эпидемии

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Цель – провести прогнозирование расходов на лечение, уход и поддержку ВИЧ-инфицированных на период действия действующей программы противодействия ВИЧ-инфекции/СПИДа (2017–2018 гг.) в Закарпатской области с использованием технологии математического прогнозирования численности официально зарегистрированных ВИЧ-инфицированных в регионе.

Методы: статистический, ретроспективный эпидемиологический, математического прогнозирования, информационно-аналитический и системного анализа.

Результаты. По прогнозам, ожидаемое количество новых случаев ВИЧ-инфекции в 2016 г. составит 87–88 человек, в 2017 и 2018 гг. – 89–90 человек и 90–91 человек соответственно. Количество официально зарегистрированных ВИЧ-инфицированных лиц на конец 2016 г. прогнозируемо составит 469–470 человек, а на конец периода реализации программы противодействия эпидемии ВИЧ-инфекции/СПИДа (2018) – 584–585 человек. Прогнозируемая сумма затрат на направление лечения ВИЧ-инфицированных в 2018 г. возрастет по сравнению с 2014 г. в 3,5 раза (в долларах США), а расходы на уход и поддержку в 2018 г. будут меньше расходов в 2014 г. на 17,6%.

Выводы. Математическое прогнозирование численности официально зарегистрированных ВИЧ-инфицированных на региональном уровне может использоваться как инструмент планирования затрат на обеспечение их лечения и ухода и поддержки.

КЛЮЧЕВЫЕ СЛОВА: математическое прогнозирование, ВИЧ-инфицированные, расходы на противодействие ВИЧ-инфекции/СПИДа.

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