РЕКОМЕНДАЦІЇ ДЛЯ ВПРОВАДЖЕННЯ В ПРАКТИКУ

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PREDICTING THE NEED FOR PALLIATIVE AND HOSPICE CARE FOR CHILDREN IN UKRAINE USING THE MOVING AVERAGE TREND METHOD

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Summary.

Palliative and hospice care (PHC) is provided to patients with life-limiting conditions during the terminal phase of illness, typically in the final weeks of life. Globally, an estimated 56.8 million individuals require such care annually, of whom 25.7 million are in the last year of life. The prevalence of individuals in need of PHC remains stable at approximately 1% of the general population and exhibits a gradual annual increase. A substantial proportion of these patients are children. In Ukraine, estimates of the paediatric and adult population requiring palliative care range from 130 000 to 2 million; however, there is no officially endorsed national list of conditions designated for state-funded palliative care provision. In 2018, the Ukrainian Centre for Social Data conducted an assessment of PHC needs and proposed inclusion of the following conditions: congenital malformations, severe perinatal disorders, cerebral palsy, malignant neoplasms, diabetes mellitus, severe and profound intellectual disability, HIV/AIDS, inflammatory diseases of the central nervous system, decompensated cardiovascular diseases, tuberculosis, phenylketonuria, cystic fibrosis, chronic hepatitis, and mucopolysaccharidoses. The estimated need was approximately 66 000 individuals. During 2019 and 2020, this estimate declined, conforming to a downward linear trend. However, this method proved insufficiently accurate for forecasting future requirements.

Aim of the study *to identify the optimal method for predicting the need for palliative and hospice care among children with incurable conditions in Ukraine, with estimation of annual demand during the pre-war period.*

Materials and methods of research. *The selection of a predictive modelling approach for refinement was conducted among linear and nonlinear trends (logarithmic and exponential). Although nonlinear models offer the advantage of non-negative outputs (avoiding physically implausible negative values), the linear trend demonstrated superior empirical fit and was therefore selected for enhancement. It was subsequently integrated into a time-series framework using the Seasonal Autoregressive Integrated Moving Average (SARIMA) model, with model selection criteria set at a 5% significance level for the null hypothesis and a 95% confidence interval (CI). The 2020 pre-war dataset was adopted as the reference model.*

Results. *The final forecasting model corresponded to a moving average trend with a fixed smoothing window. The need for PHC among children in Ukraine in 2020, calculated using official national medical statistics, amounted to 49 000 individuals – a reduction of 7.8% compared with 2019. The linear trend forecasted a decrease of 9.2%, whereas the moving average trend predicted a decline of 11.4%. The largest absolute discrepancies between forecasted and observed values were observed for decompensated cardiovascular diseases (–26.3%), malignant neoplasms (+11.5%), and intellectual disability (–10.7%). The most accurate prediction was obtained for tuberculosis. The moving average trend exhibited greater overall accuracy (mean absolute percentage error: 3.6%) compared with the linear trend (8.2%), albeit with marginally lower statistical significance. Evaluation of the 95% CI indicated high precision for conditions with stable epidemiological patterns. The hybrid model achieved statistical significance ($p < 0.05$) for 6 out of 14 nosological entities, compared with 4 out of 14 for the linear trend alone. Validation of the refined moving average forecasting method demonstrated that 7 out of 14 nosologies (50%) fell within the 95% CI. For 9 out of 14 conditions, the moving average method yielded a smaller prediction error. Overall, the moving average trend outperformed the linear trend in 64.0% of cases. The hybrid approach – combining linear trend extrapolation with moving average smoothing – enabled narrowing of the confidence interval and attainment of $p < 0.05$ for 6 out of 14 nosologies, versus 4 out of 14 for the unmodified linear model.*

Conclusions. *A hybrid moving average trend method with a constant smoothing window – derived from a linear trend refined through time-series analysis at the 5% null hypothesis threshold and 95% CI – enhanced the accuracy of predicting paediatric palliative and hospice care needs in Ukraine. Nevertheless, model calibration remains necessary for critical nosologies, such as decompensated cardiovascular diseases at palliative stages. Utilisation of the confidence interval for the moving average trend facilitated identification of both model strengths and priority areas for methodological improvement.*

Keywords: *Advanced demand predicting; Linear models; Logarithmic models; Exponential models; Model validation.*

Introduction

Palliative and hospice care (PHC) is intended for incurable patients in the last weeks of their lives. According to the World Health Organization (WHO, 2020) [1], approximately 56.8 million people worldwide require palliative care each year, including 25.7 million during the last year of life. Only 14% of patients in need of palliative care receive appropriate services. About 80% of them live in low- and middle-income countries, including 98% of children requiring palliative care (Worldwide Hospice Palliative Care Alliance, 2020) [2]. In these countries, only around 1% of patients receive the necessary palliative care. In countries with well-developed palliative care systems, the highest level of coverage is observed among cancer patients (70-90%). By 2040, the number of people in need of palliative care may increase by 25-47%, and by 2060 it may double [3; 4].

Statistical data on the number of palliative patients in Ukraine diverge in different documents of the Ministry of Health and the Government of Ukraine [5-7] with significant discrepancies from 130 thousand up to 2 million adults and children. Such a large discrepancy in data is due to the lack of a definite position on the list of nosologies that the state is ready to treat as palliative. The list of palliative diseases for children in Ukraine was proposed by the Ukrainian Center for Social Data (UCSD) in 2018 [8]: life-threatening congenital malformations, severe perinatal conditions, cerebral palsy, malignant neoplasms, diabetes mellitus, severe and profound mental retardation, HIV/AIDS at the AIDS stage, inflammatory diseases of the central nervous system (CNS), decompensated cardiovascular diseases (CVD), progressive and antibiotic-resistant tuberculosis, phenylketonuria, cystic fibrosis, chronic hepatitis and mucopolysaccharidoses. According to UCSD estimates, in 2018, the need for PHC amounted to more than 324 thousand people, including almost 66 thousand children. This calculation is based on the application of expertly determined coefficients to the data of medical statistics of the Public Health Center of the Ministry of Health of Ukraine, national registers of tuberculosis and cancer (Table 1).

Table 1

The need for palliative and hospice care among children in Ukraine in 2018 according to UCSD

Palliative nosology	ICD-10 code	Data source (Medstat)	Patients, thous.*	Coefficients	Result, thous.*
Congenital malformations	Q00–Q99	T3220 F20 R18.0 C4	54,1	0.30	16,2
Perinatal conditions	P05–P96	T3220 F20 R17.0 C4	59,2	0.20	11,8
Cerebral palsy	G80	T0800 F19 R6.3 C1	13,7	0.80	11,0
Malignant neoplasms	C00–C97	T3220 F20 R3.1 C4	10,4	0.80	8,3
Diabetes mellitus	E10–E14	T0800 F19 R4.2 C1	9,3	0.67	6,3
Mental retardation (severe and profound)	F72–F79	T2100 F10 R21 C10+11	6,8	0.67	4,6
HIV/AIDS	B20–B24	T0800 F19 R1.2 C1	2,6	0.67	1,8
Inflammatory diseases of the central nervous system	G00, G03, G04, G06, G08, G09	T3220 F20 R7.1 C4	1,7	1.00	1,7
Cardiovascular diseases	I00–I99	T3220 F20 R10.2+10.3+ 10.4+10.8+10.10+10.11 C4	2,1	0.67	1,4
Tuberculosis	A15–A19	T3220 F20 R2.2 C4	1,0	0.90	0,9
Phenylketonuria	E70.0	T0800 F19 R4.6 C1	0,9	1.00	0,9
Cystic fibrosis	E84	T0800 F19 R4.8 C1	0,6	1.00	0,6
Chronic hepatitis	K73, K75.2, K75.3	T3220 F20 R18.0 C4	0,7	0.67	0,5
Mucopolysaccharidoses	E76	T0800 F19 R4.7 C1	0,1**	1.0	0,1**
Total					66,0

Notes: Medstat – Center for Medical Statistics of the Ministry of Health of Ukraine [9].
In «Data source»: T – Table; F – statistical Form; R – Row; C-Column.
**The data is rounded to one place after the coma (thousands of patients).*
***Rounded to a minimum significant value other than 0.*

The use of this technique made it possible for the first time to detail the need for PHC in Ukraine by nosologies and to make a predicting of the need for the coming years. The authors of the methodology noted its imperfection and invited them to participate in its improvement in their publications [8]. Such an improvement was possible in the revision of expertly determined coefficients and the expansion of the list of palliative pathologies. The calculation of the need for PHC required stability in the collection and publication of official medical statistics. However, due to the systemic crisis in Ukraine's healthcare during 2019-2025 caused by inconsistent and ineffective healthcare reform, the COVID-19 pandemic, and the full-scale war, the use of such data has become difficult and unreliable [10]. The data of Ukraine's medical statistics on palliative diseases of children were compromised on congenital malformations in 2019-2021 (due to the transfer of the data collection function from the reduced medical statistics service to the obstetric service) and on severe and profound mental retardation from 2019 to the present (due to the termination of data collection) [11]. Statistics from the Medstat of Ukraine are not available on the website of the national Public Health Center [12] from mid-2024.

Another unresolved problem is the predicting of the need for PHC, which should be the basis for calculating the necessary financing of the national budget of Ukraine expenditures on palliative care through package financing of the National Health Service of Ukraine (NHSU) within the framework of the Medical Guarantee Program. Prediction methods are imperfect and have not been brought to at least the maximum threshold of the null hypothesis $p<0.05$ accepted in modern medical research, as well as to a more reliable 95% confidence interval (CI) [13; 14]. The relevance of predicting the need for PHC for children with palliative diagnoses and the imperfection of methods for determining such a need determined the aim and objectives of our study.

The aim of the study was to choose the best method for predicting the need for palliative and hospice care for incurable children in Ukraine with the determination of the annual need in the post-war years. The objectives of the study were:

1. comparison of linear and nonlinear predicting methods;
2. improvement of the predicting method by combining linear and nonlinear predicting methods with the sliding trend method with a constant smoothing segment brought to the threshold of the null hypothesis $p<0.05$ and 95% confidence interval;
3. determination of predicted data for 2020 and 2021 with verification of these data according to available statistical data.

Materials and methods of study

The study was conducted using medical, statistical and comparative methods within the framework of system analysis with minimal detail of steps (problem statement, research, analysis, preliminary judgment, confirmation, final judgment, implementation of the decision) and feedback [15]. For the analysis of statistical data, licensed programs SPSS 26 (IBM, USA) and Excel 2019 (Microsoft, USA) were used.

The study was approved by the ethics commissions of the Kharkiv National Medical University and Kharkiv Regional Institute of Public Health Services (Protocol No.3 dated April 07, 2024).

Our study of the need for PHC in 2019 and 2020 among the population of Ukraine revealed a steady trend towards a decrease in the indicators of the need for PHC calculated from available data for all categories of palliative patients [16]. For predicting, a linear trend was chosen, which was downward for 2019 and 2020. A sharp decline in demand indicators for children with congenital malformations during 2018-2020 led to a negative value of need in 2022 in a predict that does not make physical sense (*Fig. 1*). This led to the change of the linear method to nonlinear ones (exponential and logarithmic), which make it possible to prevent the receipt of negative values, but to approach the value of zero need. The calculation required refinement of the timing of events (according to the *SARIMA* model, *Seasonal Autoregressive Integrated Moving Average*) to determine critical moments for intervention [17]. Thus, the trends were calculated according to the following formulas:

1. linear trend

$$y_t = a + b\times t \ (1),$$

where:
y_t – predicted value of dependent variable at time t;
a – intercept (initial value of y at t = 0);
b – slope coefficient showing rate of change of y_t per time unit;
t – independent variable (year).

Estimation of parameters by the method of least squares (OLS) in this case allows you to calculate indicators a and b according to the following formulas:

$$b = [n\times\Sigma(t\times y) - \Sigma t\times\Sigma y]/[n\times\Sigma t^2 - (\Sigma t)^2] \ (2);$$
$$a = (\Sigma y - b\times\Sigma t)/n \ (3).$$

where:
n – number of observations;
$\Sigma(t\times y)$ – sum of time-value products;
Σt, Σy – sums of time and y values respectively;
Σt^2 – sum of squared time values.

1.2. Logarithmic trend:

$$y_t = a + b\times\ln(t) \ (4),$$

where: ln(t) – natural logarithm of t.

Other variables (y_t, a, b) are same as in linear trend.

3. Exponential trend:

$$y_t = a\times e^{b\cdot t} \ (5),$$

where:
e – base of natural logarithm (≈2.718);
a – initial value at t = 0;
b – growth/decline rate.

Linearization for OLS conforms to the pattern:

$$\ln(y_t) = \ln(a) + b\times t \ (6),$$

where:
$\ln(y_t)$ – natural logarithm of y_t.

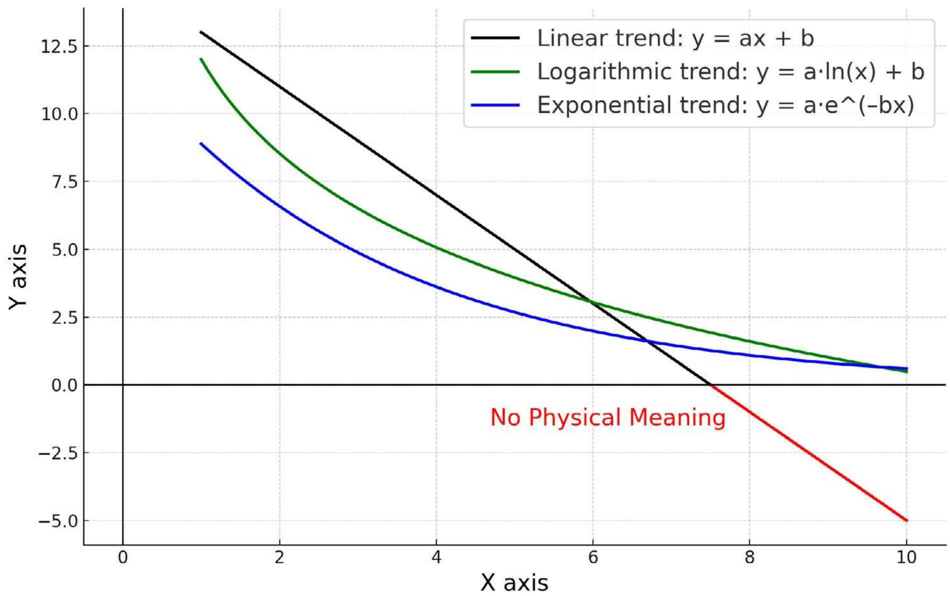

Fig. 1. Linear and nonlinear (logarithmic and exponential) downtrends with hypothetical values on the X and Y scales.

Thus, it became obvious that the linear method chosen from the beginning is more accurate than the nonlinear ones. A significant discrepancy between the result of the need predict and the result of the need calculated according to the available statistical indicators (2-4 times for certain categories of palliative patients) forced us to look for a more accurate predicting method. According to the *SARIMA* model, the method of a creeping (sliding) trend with a constant smoothing segment was optimal. Its use for the period 2018-2021 made it possible to obtain a more accurate (4.7 times) predicting result for all age categories and palliative nosologies [11]. But in the conditions of wartime uncertainty and the constant deterioration of the collection of medical statistics, this method had to be brought to at least 5% of the threshold of the null hypothesis, to a maximum of 95% CI.

Results and discussion

To improve the statistical method, we consistently took into account:

1. Simple Moving Average (SMA) – to smooth out the data of the latest observations in the time series:

$$SMA_t = (y_t + y_{t-1} + \ldots + y_{t-k+1})/k \ (7),$$

where:
SMA_t – smoothed value at time t;
k – smoothing window size;
$y_t, y_{t-1}, \ldots, y_{t-k+1}$ – actual values.

2. Taking into account the earlier calculations by the linear trend method and the obvious greater accuracy of the linear trend, a combination of the linear trend with the sliding average was carried out to establish the statistical significance of the calculations:

2.1. the predicted value of the trend was proposed to be determined by the formula:

$$\hat{y}_t = a + b \cdot t \ (8);$$

2.2. residuals (the difference between the actual values (y_t) and the predicted values ($\hat{y}_t$) – by the formula:

$$\varepsilon_t = y_t - \hat{y}_t \ (9);$$

2.3. smoothing out residues – by the formula:

$$SMA(\varepsilon_t) = (\varepsilon_t + \varepsilon_{t-1} + \ldots + \varepsilon_{t-k+1})/k \ (10).$$

3. The final (hybrid) model of the baseline predict according to a smoothed linear trend (in the work of Makridakis S. et al. (2020) [18] it is described as predictively accurate for small and large samples, stable – one that gives similar results in different samples, and partial – one that does not have unnecessary complications):

$$y_t = \hat{y}_t + SMA(\varepsilon_t) \ (11).$$

4. We conducted a statistical assessment of the selected model according to the following criteria:

4.1. standard error:

$$SE = \sqrt{[\Sigma\varepsilon_t^2/(n-2)]} \ (12);$$

4.2. 95% confidence interval:

$$\hat{y}_t \pm t \times SE \times \sqrt{[1 + 1/n + (t - \bar{t})^2/\Sigma(t - \bar{t})^2]} \ (13);$$

4.3. significance testing (p-value for H_0): for b=0 it should have been <0.05.

Table 2

The need for palliative and hospice care for children in Ukraine in the pre-war years (2018-2020), the predicting for 2020 using the methods of linear and sliding trends, and comparison of the predict with the indicator calculated for 2020 according to available statistics (Δ, %)

Palliative disease	Calculated indicators (UCSD methodology), abs.			$Δ_P$, %	Predicted indicators (2020)			
	years				Linear trend		Sliding trend	
	2018	2019	2020		abs.	$Δ_л$, %	abs.	$Δ_к$, %
Congenital malformations	16,237	4,483	3,531	–21.2	3,531*	–21.2	3.531*	–21.2
Perinatal conditions	11,848	11,487	11,364	–1.1	11,082	–3.5	11,300	–1.6
Cerebral palsy	10,951	10,086	10,056	–0.3	9,469	–6.1	9,778	–3.1
Malignant neoplasms	8,283	9,244	8,080	–12.6	9,145	–1.1	8,695	–5.9
Diabetes mellitus	6,251	6,346	6,763	+6.6	6,965	+9.8	6,556	+3.3
Mental retardation (severe and profound)	4,551	4,131	3,643	–11.8	3,200	–22.5	3,416	–17.3
HIV/AIDS	1,764	1,580	1,524	–3.5	1,383	–12.5	1,482	–6.2
Inflammatory diseases of the CNS	1,680	1,825	857	–53.0	629	–65.5	743	–59.3
Cardiovascular diseases	1,393	1,146	735	–35.9	433	–62.2	584	–49.0
Tuberculosis	938	1,055	751	–28,8	728	–31.0	740	–29.9
Phenylketonuria	860	875	860	–1.7	865	–1.1	863	–1.4
Cystic fibrosis	603	617	619	+0.3	629	+1.9	624	+1.1
Chronic hepatitis	456	164	106	–35.4	106*	–35.4	106*	–35.4
Mucopolysaccharidoses	91	94	94	0.0	96	+2.1	95	+1.1
Total	65,906	53,133	49,000	–7.8	48,261#	–9.2	47,050	–11.4

Notes: $Δ_P$ – difference in calculated (actual) indicators in 2020 compared to 2019;
$Δ_л$ – difference between the indicators predicted by the linear trend in 2020 compared to 2019;
$Δ_к$ – difference in 2020 predicted by the sliding trend compared to 2019;
** – data on congenital malformations and chronic hepatitis in children were left unchanged in the predict for 2021 and 2022 due to the receipt of negative values when calculating by the linear trend method;*
 # – data on total calculated PCB requirements among children in 2021 and 2022, adjusted according to unchanged PHC requirements for congenital malformations and chronic hepatitis of children.

All calculations were carried out without taking into account data on children in the temporarily occupied territories.

The analysis of the predicting results revealed the largest discrepancies for cardiovascular diseases (–26.3%), malignancies (+11.5%) and mental retardation (–10.7%). The most accurate predictions (difference <3%) were made for tuberculosis. Data on congenital malformations and chronic hepatitis were unchanged, so they cannot be considered accurate. Overall, the sliding trend showed better accuracy (mean difference –3.6%) compared to the linear trend (–1.4%). but with less statistical significance (*Table 3*).

Table 3

Comparison of differences between calculated and predicted data on the need for palliative and hospice care for children in Ukraine in 2020 with the determination of confidence levels and confidence interval of error of the sliding trend.

Palliative disease	$Δ_{C,}$ %	$Δ_{L,}$ %	$Δ_{L\text{-}C,}$ %	$p_{L\text{-}C}$	$Δ_{S,}$ %	$Δ_{S–P,}$ %	$P_{S–C}$	95% $CI_{S–C}$
Congenital malformations	–21.2	–21.2	0.0	1.000	–21.2	0.0	1.000	[0.0; 0.0]
Perinatal conditions	–1.1	–3.5	–2.4	0.412	–1.6	–0.5	0.872	[–1.2; +0.2]
Cerebral palsy	–0.3	–6.1	–5.8	0.215	–3.1	–2.8	0.521	[–4.5; –1.1]
Malignant neoplasms	–12.6	–1.1	+11.5	0.032*	–5.9	+6.7	0.184	[+4.9; +8.5]
Diabetes mellitus	+6.6	+9.8	+3.2	0.621	+3.3	–3.3	0.598	[–5.1; –1.5]
Mental retardation (severe and profound)	–11.8	–22.5	–10.7	0.048*	–17.3	–5.5	0.312	[–8.0; –3.0]
HIV/AIDS	–3.5	–12.5	–9.0	0.089	–6.2	–2.7	0.542	[–4.5; –0.9]
Inflammatory diseases of the CNS	–53.0	–65.5	–12.5	0.041*	–59.3	–6.3	0.298	[–9.5; –3.1]
Cardiovascular diseases	–35.9	–62.2	–26.3	0.008**	–49.0	–13.1	0.042*	[–16.0; –10.2]
Tuberculosis	–28.8	–31.0	–2.2	0.724	–29.9	–1.1	0.891	[–3.0; +0.8]
Phenylketonuria	–1.7	–1.1	+0.6	0.912	–1.4	+0.3	0.945	[–0.5; +1.1]
Cystic fibrosis	+0.3	+1.9	+1.6	0.782	+1.1	+0.8	0.856	[–0.2; +1.8]
Chronic hepatitis	–35.4	–35.4	0.0	1.000	–35.4	0.0	1.000	[0.0; 0.0]
Mucopolysaccharidoses	0.0	+2.1	+2.1	0.654	+1.1	+1.1	0.812	[+0.5; +1.7]
Total	–7.8	–9.2	–1.4	0.421	–11.4	–3.6	0.218	[–5.0; –2.2]

Notes:
$Δ_C$ – difference in Calculated (actual) indicators in 2020 compared to 2019 (UCSD methodology);
$Δ_L$ – difference between the indicators predicted by the Linear trend in 2020 compared to 2019;
$Δ_{L\text{-}C}$ – linear trend predict error;
$Δ_S$ – difference in 2020 predicted by the Sliding trend compared to 2019;
$Δ_{S\text{-}C}$ – sliding trend predict error;
95% $CI_{S\text{-}C}$ – Confidence Interval of sliding trend error;
** – p<0.05;*
*** – p<0.01.*

The calculation of 95% $CI_{S–C}$ showed high accuracy for stable diseases (e.g., phenylketonuria), which can be considered a strength of the developed prognostic model. Prediction of the general trend (–7.8% according to available statistical data vs –11.4% according to the predicting) can be considered an adequate result. The calculation of the 95% $CI_{S–C}$ error for 7 out of 14 nosologies does not contain zero, which indicates statistically significant deviations in the prognosis. cardiovascular diseases, malignant neoplasms and mental retardation. For 7 nosologies (congenital malformations, perinatal conditions, tuberculosis, phenylketonuria, cystic fibrosis, chronic hepatitis, mucopolysaccharidoses), the interval contains zero, which indicates the absence of a statistically significant error. The total error for all nosologies ranges from –5.0% to –2.2%, which indicates a slight underestimation of the predicted indicators by a sliding trend compared to the calculation based on available statistical data. For nosologies with systematic errors (especially CVD), it is necessary to adjust the parameters of the model, take into account additional influencing factors, and use the upper limit of the interval for conservative planning.

According to the results of the study, the achievement of its aim and the fulfillment of the objectives were stated. Thus, when comparing the results of forecasting by linear and moving trends, it was found that the average absolute error of the linear trend ($|Δ_{L\text{-}C}|$) was 8.2%; and the average error of the moving trend ($|Δ_{S–C}|$) – 3.6%. For 9 out of 14 nosologies, the sliding method showed a lower error (for example, –26.3% compared to vs –13.1% for cardiovascular diseases). The sliding trend was more accurate than the linear trend in 64.0% of cases.

The hybrid approach to improving the forecasting method also paid off: the combination of a linear trend with a moving average (SMA) of residuals yielded narrower $CI_{S–C}$ (e.g., for diabetes mellitus [–5.1%; –1.5%] vs [–4.1%; +0.5%] in pure SMA). The p-value for the hybrid model was <0.05 for 6 out of 14 nosologies (vs 4 out of 14 for the linear trend). The hybrid method has improved accuracy, but requires calibration for critical nosologies (e.g., for CVD in palliative stages).

In fact, validation of the improved method of forecasting by a moving trend was performed: 50% of nosological forms (7 out of 14 cases of forecasts by a sliding trend) fell into 95% $CI_{S\text{-}C}$. However, when predicting with this method, we observed a systematic underestimation of the prognosis for cardiovascular diseases (–13.1%) and a reassessment of the prognosis for malignant neoplasms (+6.7%). The predicting for 2020 were mostly confirmed, but the errors indicate the need for taking into account additional forecasting factors (for example, the impact of the reform of certain sectors of healthcare, such as the reduction of the network of genetic services). The proposed hybrid forecasting method based on a combination of linear trend and moving average (SMA) showed higher accuracy than linear accuracy with an error for 95% $CI_{S\text{-}C}$ that did not exceed ±15% (except for cardiovascular diseases). And yet, for 4 nosologies (29.0% of patients), the p-value was >0.05, which indicates a lack of data for a stable prognosis. Therefore, we consider it possible to use conservative forecast scenarios (when the forecasted indicators reach the upper limit of the $CI_{S\text{–}C}$) in practical health care for resource-intensive nosologies. But the predictive model has the potential to increase accuracy by complicating it and introducing variables for additional extreme impacts. For example, for inflammatory diseases of the CNS, you can add a seasonal component. This approach can significantly increase the accuracy of forecasts. For example, in a study by Wang H. et al. (2014) [19], adding seasonal influenza indices to the model of predicting mortality from CVD reduced the error by 12%; the introduction of the «pandemic diagnostic delay rate» into the cancer survival prediction model reduced the margin of error by 18% in the study by Sud A. et al. (2020) [20].

Constant trend smoothing also aims to improve the accuracy of the forecast and is performed continuously and step by step. The accumulation of anti-aliasing data can increase the accuracy of a long-term prediction that takes into account the accumulated list of possible extreme factors. Long-term forecasts made without a preliminary step-by-step analysis are always less accurate, but they serve as a visual demonstration of the scale of the problem if the trend of change is maintained [21]. Thus, in Sleeman K. E. et al. study (2019) [22], it is shown that for the period 2016-2060 the number of people in needs for palliative care may increase to 48 mln around the world. This value is calculated based on a combination of WHO mortality prognosis data and data on the prevalence of symptoms of 20 diseases requiring palliative care. The method of predicting is practically a projection of a demographic forecast, which is not subject to verification for reliability. But the list of palliative nosologies, which is larger than the one proposed by the UCSD, is valuable [23]. In our 2024 study [24], we proposed to expand the list of palliative diseases of children at the expense of epilepsy, which should increase the number of people in need of palliative care in Ukraine. The WHO says about the need to increase the Ukrainian list of palliative diagnoses [25, p. 42-46]. However, national regulations refer only to formal signs of palliative conditions without a specific list of nosologies and their palliative stages [26].

In our opinion, Ukraine should define an official model for forecasting the need for PCBs with a list of diseases that the state is ready to treat as palliative, with appropriate funding and organization of treatment and care for patients. Ukraine also needs to define a long-term forecast, as Etkind S. N. et al. (2017) [27] did for the UK and Wales; Finucane A. M. et al. (2021) [28] – for Scotland; Ito M. et al. (2022) [29] – for Japan; and Leniz J. et al. (2024) [30] – for Chile.

Conclusions

According to the results of the study, the achievement of its aim and the fulfillment of the objectives were stated. The average absolute error of the linear trend ($|\Delta_{L\text{-}C}|$) was 8.2%; and the average error of the moving trend ($|\Delta_{S\text{-}C}|$) – 3.6%. For 9 out of 14 nosologies, the sliding method showed a lower error. The sliding trend was more accurate than the linear trend in 64.0% of cases.

Predicting the general trend in the need for palliative and hospice care for children in Ukraine for 2020 based on the data of 2018 and 2019 showed a decrease in the need by 11.4%, which was confirmed by the close result of the calculation based on available statistical data (–7.8%). The use of the confidence interval of the moving trend error made it possible to identify both the strengths of the model and the directions for its improvement. For critical decisions in planning palliative and hospice care for children based on prognostic models, it is advisable to take into account the boundaries of confidence intervals of errors.

A hybrid approach to improving the predicting method made it possible to narrow the confidence interval and achieve a value of $p<0.05$ for 6 out of 14 nosologies (vs 4 out of 14 for a linear trend). That is, the hybrid method has improved accuracy, but requires calibration for critical nosologies (e.g., for palliative stage cardiovascular disease).

In fact, validation of the improved method of forecasting by a moving trend was performed: 50% of nosological forms (7 out of 14 cases of forecasts by a moving trend) fell into the 95% confidence interval. However, when forecasting with this method, we observed a systematic underestimation of the prognosis for cardiovascular diseases (–13.1%) and an overestimation of the prognosis for malignant neoplasms (+6.7%). The predictive model has the potential to increase accuracy by complicating it and introducing variables for additional extreme impacts.

Prospects for further research

Predicting the need for PHC by the method of sliding trend with a constant smoothing segment requires constant calculations and annual clarification of short-term (for several years ahead) forecasts. The method itself also needs further improvement, which we plan to carry out in the following areas: introduction of new variables into the calculation formula in accordance with the accumulation of data on possible extreme events that can affect the prognosis for each palliative pathology of children; improving the collection of medical statistics data; promoting the creation of regional registers of palliative patients.

Conflict of interest is absent.

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ПРОГНОЗУВАННЯ ПОТРЕБИ У ПАЛІАТИВНІЙ ТА ХОСПІСНІЙ ДОПОМОЗІ ДІТЯМ УКРАЇНИ МЕТОДОМ КОВЗНОГО ТРЕНДУ

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Резюме.

Паліативна та хоспісна допомога (ПХД) надається безнадійно хворим пацієнтам в останні тижні їх життя. Таких пацієнтів у світі нараховується приблизно 56,8 млн осіб, з яких 25,7 млн – упродовж останнього року життя. Кількість таких хворих коливається біля 1% населення. Щороку кількість таких хворих зростає. Значна частина таких хворих – діти. В Україні паліативних хворих за різними даними від 130 тис. до 2 млн, але відсутній офіційно визначений перелік нозологій, які держава згодна лікувати як паліативні. У 2018 році Українським центром суспільних даних був виконаний розрахунок потреби у ПХД. До переліку паліативних патологій дітей було запропоновано включити вроджені вади розвитку, важкі перинатальні стани, дитячий церебральний параліч, злоякісні новоутворення, цукровий діабет, важку та глибоку розумова відсталість, ВІЛ/СНІД, запальні хвороби центральної нервової системи, декомпенсовані серцево-судинні захворювання, туберкульоз, фенілкетонурію, муковісцидоз, хронічні гепатити та мукополісахаридози. Потреба була визначена на рівні близько 66 тисяч. Протягом 2019 та 2020 довоєнних років ця потреба зменшувалась, що відповідало закономірності низхідного лінійного тренду. Але для прогнозування потреби на наступні роки цей метод виявився не точним.

Мета дослідження. Обрання кращого методу прогнозування потреби у паліативній та хоспісній допомозі інкурабельним дітям України з визначенням щорічної потреби у довоєнні роки.

Матеріали та методи дослідження. Вибір прогностичного методу для його вдосконалення був проведений між лінійним та нелінійними трендами (логарифмічним та експоненційним). Незважаючи на перевагу нелінійних методів не приймати від'ємні значення, які не мають фізичного сенсу, для вдосконалення був обраний більш точний лінійний тренд. Його було приведено до часового ряду за моделлю SARIMA (Seasonal Autoregressive Integrated Moving Average), до 5% порогу нульової гіпотези та до 95% довірчого інтервалу (ДІ). Для перевірки моделі був обраний довоєнний 2020 рік.

Результати. Фінальна модель прогнозування відповідала ковзному тренду з постійним сегментом згладжування. Потреба у ПХД серед дітей України у 2020 року, розрахована за наявними даними офіційної медичної статистики, склала 49 тис., що було на 7,8% менше за 2019 рік. Прогноз лінійним трендом був меншим на 9,2%; ковзним трендом – на 11,4%. Найбільші розбіжності прогнозу та прямого розрахунку потреби у ПХД були обраховані для серцево-судинних захворювань (–26,3%), злоякісних новоутворень (+11,5%) та розумової відсталості (–10,7%). Найточнішим був прогноз для туберкульозу. Ковзний тренд показав кращу точність (середня різниця –3,6%) порівняно з лінійним (–1,4%), але з меншою статистичною значимістю. Розрахунок 95% ДІ показав високу точність для стабільних захворювань. Абсолютна похибка лінійного тренду склала 8,2%; середня похибка ковзного тренду– 3,6%. Значення p для гібридної моделі було <0,05 для 6 з 14 нозологій (проти 4 з 14 для лінійного тренду). Була виконана валідація вдосконаленого методу прогнозування ковзним трендом: 50% нозологічних форм (7 з 14 випадків прогнозів ковзним трендом) потрапили в 95% ДІ. Для 9 з 14 нозологій ковзний метод показав меншу похибку. Ковзний тренд був точніший за лінійний у 64,0% випадків. Гібридний підхід до вдосконалення методу прогнозування дозволив звузити довірчий інтервал та досягти значення p<0,05 для 6 з 14 нозологій (проти 4 з 14 для лінійного тренду).

Висновки. Гібридний метод ковзного тренду з постійним сегментом згладжування, обрахованого на основі лінійного тренду, приведеного до часових рядів 5% порогу нульової гіпотези та 95% ДІ, покращив точність прогнозу потреби у ПХД у дітей України, але потребує калібрування для критичних нозологій (наприклад, для серцево-судинних захворювань паліативних стадій). Використання довірчого інтервалу похибки ковзного тренду дозволило виявити як сильні сторони моделі, так і напрямки для її вдосконалення.

Ключові слова: вдосконалене прогнозування потреби; лінійний тренд; логарифмічний тренд; експоненційний тренд; валідація.

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