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THE FORMATION OF ADEQUATE SAMPLES FOR THE LONG-TERM ASSESSMENT OF THE LEVEL OF GLYCEMIA IN PATIENTS WITH DIABETES MELLITUS

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ABSTRACT

An inaccurate value of blood glucose concentration in patients with diabetes mellitus can lead to mistakes in treatment. To determine the right treatment, you need to improve accuracy. Authors of the article proposes to use adaptive statistical methods for increasing accuracy, which work well for a small number of repeated measurements under conditions of uncertainty of external factors.

Keywords: glucose control, accuracy, diabetes, moving average.

INTRODUCTION

When appointing, monitoring and correcting the treatment of diabetes mellitus, it is important to have accurate glucose concentrations in the blood. Increasing the accuracy of control of any physical quantity can be provided in various ways, for example:

Increase in the accuracy of single measurements, associated with an increase in the sensitivity of devices;

Use of increased number of multiple measurements;

The application of statistical methods to improve the accuracy of measurements with a small number of duplicate measurements.

There are cases of hyper- and hypoglycemia among patients receiving treatment for diabetes mellitus. In addition to insufficient accuracy of measuring equipment, these cases are caused by the influence on the level of glycemia in addition to drugs and other factors (for example, nutrition and exercise). Accounting for these factors is necessary to designate the right treatment and minimize its side effects.

LITERATURE REVIEW

Evaluation of blood glucose and the accuracy of determining the concentration of glucose in the blood affect the course of the disease and the quality of treatment. Among the factors influencing the accuracy of the definition of glycemia, it is possible to isolate the accuracy of glucometers. Studies [1-3] show that 40% of the personal equipment used to measure blood sugar do not meet the accuracy requirements for personal medical measuring devices. At the same time,

because of incorrect determination of blood sugar level, a large number of latent mistakes in treatment can occur. To ensure the correct determination of blood glucose level and avoiding hyper and hypoglycemic conditions, it is necessary to introduce new technologies for measuring and processing data.

METHODOLOGY

Among the various statistical methods of quality management, the most promising in solving this problem are methods of adaptive control [4-8], they allow you to take into account the unpredictable effect of external unknown factors on the monitored parameter. Adaptive management methods are adjusted to continuously changing external conditions, allowing to anticipate the trend of change of the monitored parameter, because they make it possible to select the most effective methods at the level of statistical calculations, which, in turn, allows, with insufficient a priori information or in conditions of uncertainty, to lead to the best possible result. In addition, such systems have proven themselves in various fields of technology and are used in the manufacture of expensive high-precision components and components, which allows us to conclude that they are effective.

Among the adaptive management methods, it is worth mentioning the moving average methods because they allow you to take into account information about the last few measured values of the monitored parameter. The simple moving average [9] is numerically equal to the arithmetic mean of the values of the original function for the specified period t and is calculated by the formula

$$\frac{x}{t} = \frac{x_t + x_{t-1} + \ldots + x_{t-i} + \ldots + x_{t-n+2} + x_{t-n+1}}{n}, \quad (1)$$

where x_t – the value of a simple moving average at a point t; n – the number of values of the original function for calculating the moving average (smoothing interval); x_{t-i} – the value of the original function at the point (t-i).

To evaluate the effectiveness of the proposed method of adaptive control, an accuracy factor is introduced [10], which is the ratio of the root-mean-square deviation after the introduction of the correction to the original parameter:

$$\psi_T = \frac{y}{} \quad (2)$$

Thus, the introduction of an adjustment to the control system is effective for values of the coefficient of accuracy increase ψ_T less than unity. However, applying the coefficient of increase in accuracy ψ_T as a criterion for assessing the effectiveness of the introduced adjustments in the management system, for ease of understanding of the results obtained, an efficiency score is also introduced - improvement:

$$= (1 - \psi_T)\ 100\% \quad (3)$$

Obtained improvement μ, measured in percent, gives an idea of the change in the effectiveness of the proposed method for introducing adjustments into the management system.

In order to increase the effectiveness of the proposed method, it is possible to introduce additional correction factors, selected in such a way that the efficiency of the introduced control (improvement) is maximum. In this case, the control will be performed not on a simple moving average, but on the calculation of various combinations of moving averages and correction factors, which will allow us to identify the most effective combinations of calculated values in each specific case.

Based on known studies and classical mathematical models, several formulas can be proposed that could be used to introduce corrections when calculating the required amount of a drug to maintain blood glucose concentration:

1 $k_1 \overline{x_i}$;

2 $k \overline{x_{i-1}} + k_2 \left(\overline{x} + \overline{x}\right)$;

3 $k \overline{x} + k_2 \left(\overline{x} + \left(\overline{x_i} + k \overline{x}\right)\right)$;

4 $k_1 \left(\overline{x_i} - \overline{x_{i-1}}\right)$;

5 $k_1 \overline{x_{i-2}} + k_2 \left(\overline{x_{i-2}} - \overline{x_{i-1}}\right) + k_3 \left(\overline{x_i} - \overline{x_{i-1}} - \overline{x_{i-2}}\right)$;

6 $k_1 \left(\overline{x_i} - \overline{x_{i-1}}\right) + k_2 \left(\overline{x_i} - \overline{x_{i-1}}\right)^2$;

7 $k_1 \left(\overline{x_i} - \overline{x_{i-1}}\right) + k_2 \left(\overline{x_i} - \overline{x_{i-1}}^2\right) + k^3 \left(\overline{x_i} - \overline{x_{i-1}}\right)^3$,

where $\overline{x_i}$ – moving average at the *i*-th step, obtained from the last three values of the measured glucose concentration in the blood; k_1 - the correction factor, selected in such a way that the efficiency of the input control is the greatest.

The basement of this method is calculation moving average of last three values. It means that the first three positions of cutting edge still the same, so $\overline{x_1} = x_1$, $\overline{x_2} = x_2$, $\overline{x_3} = x_3$. All other positions calculates as $\overline{x_i} = x_i - f(k, \overline{x_i})$, where $f(k, \overline{x_i})$ – formula for adjustment calculation, for which $\overline{x_i}$, $\overline{x_{i-1}}$, $\overline{x_{i-2}}$ is the average of previous three values [11]:

$$x'_i = \frac{x_{i-1} + x_{i-2} + x_{i-3}}{3}. \quad (4)$$

Separately, it should be noted that the proposed methodology is described in a series of In ISO and IEC standards [12-14], and regulates different actions for different laws of distribution of the measured value on the basis of mathematical dependencies of known distribution laws. However, the actual distribution law of the measured glucose concentration in the blood is not known in practice [3], in connection with this feature, the use of adaptive management methods is proposed, which will allow selecting an effective treatment in conditions of uncertainty in the absence of a priori information.

DATA ANALYSIS

As a sequence of measured values of blood glucose concentration, the data taken into account by the glucometer of statistics are ure 1

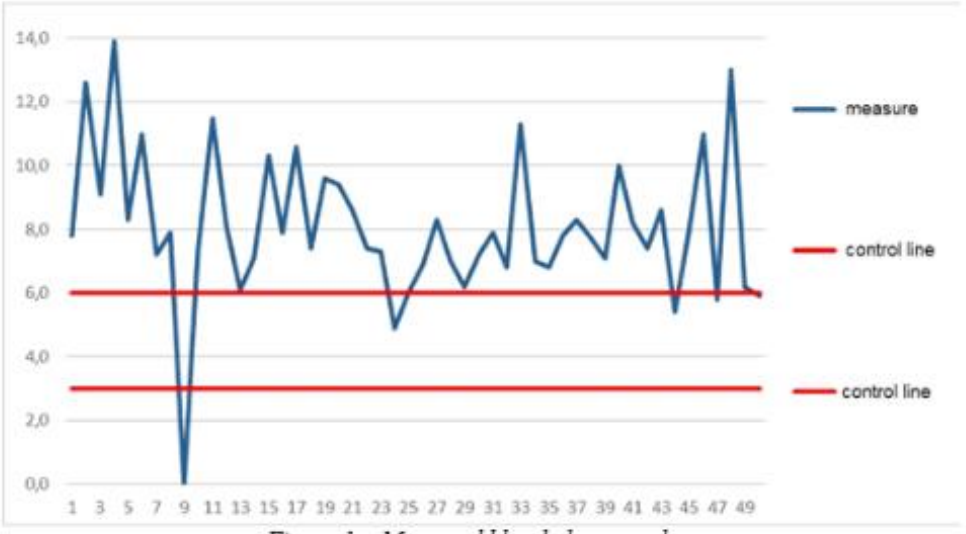

Figure 1 – Measured blood glucose values

The effectiveness of the proposed method for calculating corrections for monitoring glucose concentration in the blood was evaluated, the results are shown in figures 2, 3, 4. To illustrate the results, statistics on 50 measured values were taken

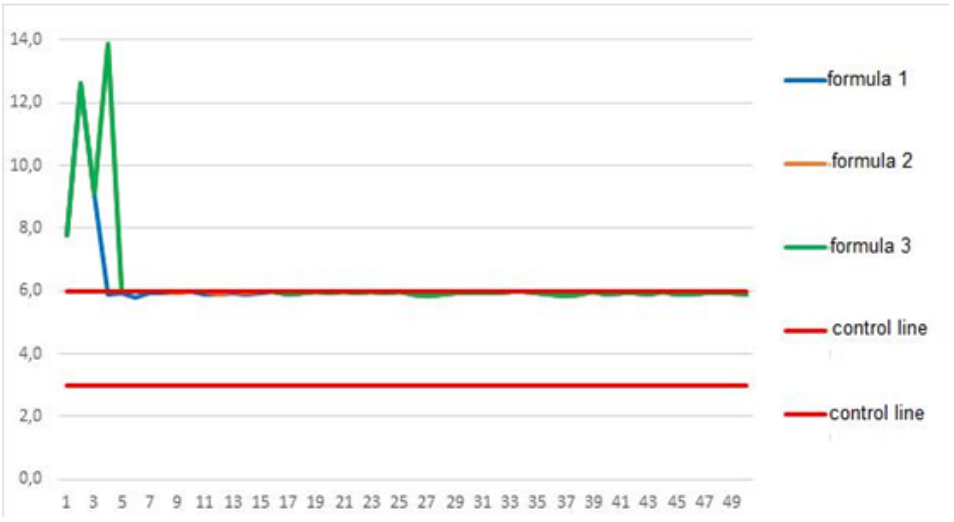

Figure 2 – The results of the adjustments to formulas 1, 2, 3 in the control of the concentration of glucose in the blood

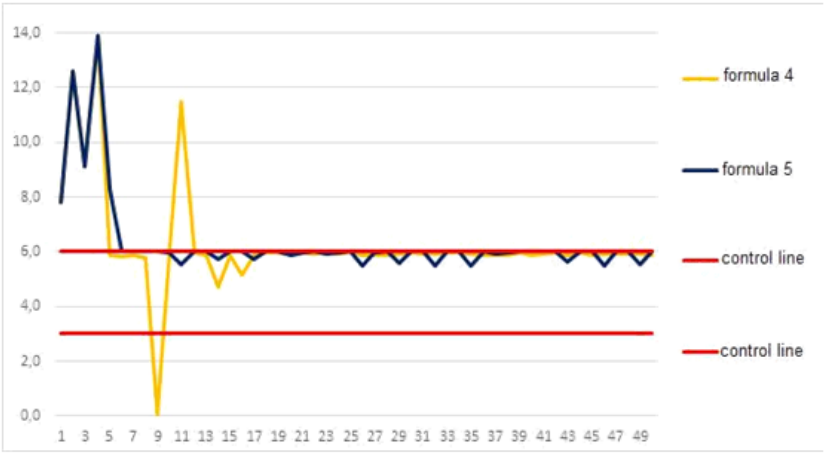

Figure 3 – The results of adjustments to formulas 4, 5 in the control of blood glucose

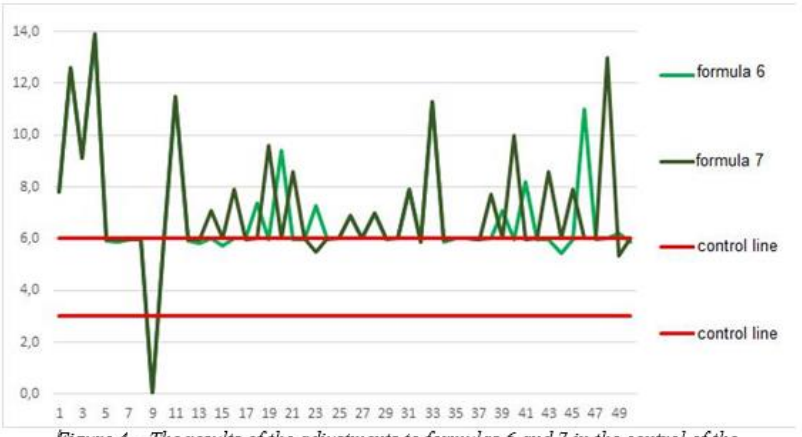

Figure 4 – The results of the adjustments to formulas 6 and 7 in the control of the concentration of glucose in the blood

According to the presented results of the conducted studies it can be concluded that:

the introduction of adjustments in the control of glucose concentration by the methods of adaptive management as a whole gives a positive effect and allows you to meet the control boundaries;

formulas 4, 6, and 7 are ineffective for the solution of the stated problem and lead to an uncontrolled derivation of the measured value from the control boundaries of the glucose concentration in the blood.

DISCUSSION

The proposed method of adaptive control to control the concentration of glucose in the blood in patients allows you to keep the controlled parameter within the specified limits. Moreover, according to the proposed formulas for calculating the introduced corrections, the values of the coefficient of accuracy increase by 50 measurements reach ψ_T = 46%, which indicates an improvement of μ = 54%. The proposed method for making adjustments, based on adaptive control over the moving average, can be used in the treatment in individual devices for controlling blood glucose and calculating the required amount of the drug.

CONCLUSION

According to the presented results of the conducted researches it is possible to draw conclusions:

The introduction of adjustments in the control of glucose concentration by the methods of adaptive control as a whole gives a positive effect and allows you to meet the control boundaries;

The most effective variations of the moving average and correction factors are determined.

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