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USING MACHINE LEARNING ALGORITHMS TO PREVENT THE RISK OF MATERNAL COMPLICATIONS DURING PREGNANCY

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ABSTRACT. The publication presents the results of the drafting, analysis of the use of artificial intelligence technologies in the sphere of healthcare on the example of determining the risk of maternal complications during pregnancy, as well as the results of an online survey of women of reproductive age in the Republic of Uzbekistan for the use of the developed mobile application during pregnancy. Data processing methods were used using built-in Python libraries with automatic statistical data processing modules, and an online survey was conducted by means of Google Forms. The results showed high accuracy in predicting pregnancy complications. This research contributes to the digitalization of healthcare in general and helps to early identification of risks to maternal health. The analysis showed that blood glucose levels, age and blood pressure may significantly affect the health of pregnant women. Based on these data, a random forest model was built with an accuracy of 92.15%. In addition, digital medical products have been developed, and the survey demonstrated a willingness to use mobile applications to examine health status. The survey showed that 84.4% of women are ready to use a mobile app during pregnancy, and more than 60% of them even with a paid subscription. The developed digital software product in the form of a mobile application using machine learning algorithms is an alternative approach of preventing maternal complications during pregnancy in women.

KEYWORDS: machine learning, digitalization, maternal health, Random Forest, online survey

ИСПОЛЬЗОВАНИЕ АЛГОРИТМОВ МАШИННОГО ОБУЧЕНИЯ ДЛЯ ПРОФИЛАКТИКИ РИСКА МАТЕРИНСКИХ ОСЛОЖНЕНИЙ ПРИ БЕРЕМЕННОСТИ

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РЕЗЮМЕ. В публикации представлены результаты разработки, анализа использования технологий искусственного интеллекта в здравоохранении на примере определения риска материнских осложнений при беременности, а также результаты онлайн-опроса женщин репродуктивного возраста Республики Узбекистан на предмет использования разработанного мобильного приложения во время беременности. Были использованы методы обработки данных при помощи встроенных библиотек программного обеспечения Python с автоматическими модулями статистической обработки данных, а также проведен онлайн-опрос посредством Google Forms. Результаты показали высокую точность прогнозирования осложнений беременности. Это исследование вносит вклад в цифровизацию здравоохранения и помогает в раннем выявлении рисков для здоровья матерей. Анализ показал, что уровень глюкозы в крови, возраст и кровяное давление существенно влияют на здоровье беременных женщин. На основе этих данных была построена модель случайного леса с точностью 92,15%. Кроме того, были разработаны цифровые медицинские продукты, и опрос продемонстрировал готовность использовать мобильные приложения для отслеживания состояния здоровья. Опрос показал, что 84,4% женщин готовы пользоваться мобильным приложением во время беременности, и более 60% из них даже при условии платной подписки. Разработанный цифровой программный продукт в виде мобильного приложения с использованием алгоритмов машинного обучения является альтернативным способом профилактики материнских осложнений во время беременности у женщин.

КЛЮЧЕВЫЕ СЛОВА: машинное обучение, цифровизация, материнское здоровье, случайный лес, онлайн-опрос

INTRODUCTION

There are different approaches to monitoring the progress of digital health development in the world, one of the indicators of which, among others, is the presence of the “mobile healthcare” [4]. Digitalisation of healthcare is also intended to provide greater transparency and access to patient data, increase people’s knowledge and confidence, and enable them to become active partners in managing their health and wellbeing [6]. Those who do so are highly likely to adopt healthier lifestyles, leading to improved clinical outcomes and reduced hospitalisation rates [10].

Maternal mortality worldwide remains an acute issue, and the efforts made by all countries have seen some progress overall, but it still remains at high levels. For example, the global maternal mortality ratio (MMR) for 2020 is estimated at 223 maternal deaths per 100,000 live births (uncertainty interval (UI) 202–255), compared with 227 in 2015 (UI 211–246) and 339 in 2000 (UI 319–360): a decrease of one third (34.3%) over the full 20-year period. The average annual rate of decline (AAR) of global MMR was 2000–2020. 2.1% (IN 1.3–2.6%), meaning that from 2000 to 2020, on average, the global MMR declined by 2.1% annually, although progress during this period was uneven [11].

In Uzbekistan, various estimates of maternal mortality decreased from 41 per 100,000 live births in 2000 to 29 per 100,000 live births in 2017. However, this is more than twice the average for the WHO European Region (13 maternal deaths per 100,000 live births), and higher than the rates in Tajikistan and Kyrgyzstan [7].

According to the official statistics, maternal mortality in the Republic of Uzbekistan in 2021 and 2022 was 130 cases per year, compared to 2017–2020, when maternal mortality exceeded an average of 155 cases [5].

Providing more services outside of hospitals and closer to home through digital and innovative technologies, including mobile and social media, will make it easier for people to access health services when and how they want, tailored to local needs. Thus, the app we developed for patients and nurses to predict maternal health risk during pregnancy is one example of the processes of digitalisation of health care in Uzbekistan.

In Uzbekistan, due to the increase in the number of births and, consequently, the increased risk of maternal complications during pregnancy, the most pressing issue is the paradigm shift towards digitalisation of health care. Efforts are being made both at the national level and at the level of individual initiatives [3]. Certain difficulties in enhancing the effect of the

practical use of such initiatives in the field of digitalization and artificial intelligence include insufficient funding, immaturity of the regulatory framework, access to national electronic databases, and a lack of digital competencies among doctors and nurses [2].

MATERIALS AND METHODS

This study analysed open data bases [1] and conducted an anonymous online survey of 105 women of reproductive age in the Republic of Uzbekistan on the possible future use of digital software products and their monetisation. Methods of data processing were used with the help of built-in libraries of Python software: NumPy — used for processing multidimensional arrays; Pandas — for analysis and construction of summary tables of data; Scikit-learn contains classification and regression algorithms, allows clustering, validation and selection of machine learning models; SciPy used for scientific calculations with automatic modules of statistical data processing (analogue of STATISTICA 10.0), and an online survey was conducted through the open resource Google Forms from Google.

RESULTS AND DISCUSSION

We improved the accuracy and precision of an algorithm based on machine learning and artificial intelligence for predicting maternal health risk in pregnant women. Many maternal deaths are associated with pregnancy complications due to lack of awareness of maternal health measures during gestation and postpartum period. This is more common in rural areas and among low-income families in developing countries. Continuous monitoring of the health status of the pregnant woman during pregnancy is required to ensure normal foetal development and successful delivery.

The data were collected from various hospitals, clinics, maternal health services using Internet of Things (IoT) risk monitoring system, based on it a number of foreign researchers have conducted similar studies [8, 12]. Age, systolic blood pressure (BP), diastolic BP, blood glucose level and heart rate (HR) were used to determine the risk level. The predicted level of risk intensity during pregnancy took into account the data from each of these parameters [9]. Based on the analysis of these hyperparameters, machine learning algorithms were developed with varying accuracy in predicting maternal risk of pregnancy complications.

A total of 1014 pregnant women participated in the study, 272 (27%) of them were at the high risk of maternal complications, 406 (40%) at the low risk and 336 (33%) at the intermediate risk. The mean of the column by age was 30 years. The median value by age was 26 years. The minimum value by age was 10 years and the maximum value by age was 70 years. The range of the data frame was 10 to 70 years and the standard deviation was 13.5 years. In the age hyperparameter, the most frequent groups under 30 years were 23, 19, 17 and 15 years. The overall age data were grouped into categories: 54.3% adults, 40% youth, 5.3% children and 0.4% elderly. Hyperparameter correlation analyses were as follows: age/risk level — 55%, age/HR — 73%, systolic BP/body temperature — 92%, systolic BP/diastolic BP — 66%, diastolic BP/risk level — 79%, and diastolic BP/blood sugar — 58%.

After a number of experiments on training the data using machine learning and neural networks, we settled on the random forest algorithm, which gave the best result. A random forest contains a set of decision trees representing an individual instance of the input data classification. The random forest technique considers the instances individually, taking the one with the most votes as the selected prediction. Thus, random forest allows any classifiers with weak correlations to produce a strong classifier. We chose random forest because it is one of the most accurate training algorithms available, and it takes quite little time to train. In addition, random forest can work with a dataset that has feature values with different scales, so we do not need to perform normalisation or feature scaling.

By analysing an open data set, we can conclude that blood glucose levels are the most important variable in determining maternal risk levels. Pregnant women with high blood glucose levels tend to have a high health risk. More than 75% of pregnant women with a sugar reading of 8 or higher have a high health risk. Blood sugar also has a relatively strong positive correlation with age, systolic and diastolic BP, so older pregnant women with high systolic and diastolic BP should be vigilant. Age is also a fairly important variable, as the health risks for pregnant

women appear to begin to increase beginning at age 25 years. For systolic and diastolic BP, these two variables do have a strong relationship, as evidenced by the correlation coefficient value of 0.79. As for temperature, this variable does not give much information because more than 79% of the total value is 36.6 °C. But from this variable we know that pregnant women with a body temperature above 37 °C tend to have a higher health risk. And the last parameter, heart rate is the least significant variable to determine the health level of pregnant women. We built a classification model using random forest algorithm for this dataset. With the original dataset, we obtained a maximum accuracy of 86.7%. But after we performed cleaning of the data by removing outliers and unnecessary variable, the accuracy increased to 89.16%. This shows that the model gives better training results with the preprocessed dataset. We also performed index tuning to get the best result for the random forest algorithm. By using the best obtained results of indicator tuning, the model is able to provide higher accuracy which was 92.15% after a number of experiments.

After developing a machine learning-based model, we developed a number of digital software products (WEB application, Android and iOS mobile application, and a Telegram bot) for further use in practical health care. In order to explore further funding and monetisation of the developed digital products, we also investigated how much women are willing to pay for the right to use our digital products.

The questionnaire was developed based on Google Forms technology and contained a series of population, sociological, motivational and logistical questions. A total of 105 women participated in the study. The age structure of the sample was as follows: 54.3% of the female participants were aged 18–25 years, 23.8% were aged 26–35 years, 14.3% were aged 35–45 years and 7.6% were over 45 years. Of these, 82.6% lived in urban areas and 17.4 % lived in the countryside. In addition, 52.4% of the participants had no children, while 47.6% had one or more children.

Among the 105 respondents, 63.8% use mobile applications to monitor their health, while 36.2% do not use such applications. If such mobile applications are available, 91.4% are willing to use them, while 8.6% do not want to use them.

When assessing the positive aspects of such mobile applications, 56.2% of respondents noted their convenience, 27.6% — availability, 12.4% — quality, and 7.4% — speed. If we take the developed Homila AI app, 84.4% of the respondents will use it during pregnancy to assess maternal risk, while 15.2% of the participants will not.

Out of 105 respondents, 44.8% will use it every day, 34.3% will use it every week, 9.5% will use it every month and 11.4% will not use it. 64.8% of respondents believe that all 3 modules of Homila AI are equally useful, 28.6% believe that the module of artificial intelligence for assessing the risk of maternal complications is the most useful, 17.1% believe that the module of risks and complications (according to the regulatory document of the Ministry of Health of the Republic of Uzbekistan) is the most useful, and 12.4% believe that the module of addresses and geoposition of perinatal centres in the Republic of Uzbekistan is the most useful.

To increase the attractiveness of Homila AI mobile application, users suggest adding the following functionality (it was possible to choose several modules): module of monitoring for fetal development — 37.1%, module of remote online consultations — 34.3%, module for measuring weight gain during pregnancy — 30.5%, module for determining the date of birth of the future child — 25.7%, ovulation calendar and module on benefits for pregnant women — 21% each. Also 12.4% of respondents believe that three modules are enough in the original mobile application, while 41.9% prefer to have all the above-mentioned modules.

When assessing the design of a mobile application, 64.8% found it convenient, 30.5% found it attractive, 1.9% found it uncomfortable, and 2.9% found it unattractive. To assess the financial sustainability of the original mobile application, 44.8% of respondents expressed willingness to purchase a paid subscription, while 55.2% are not ready to do so. When new modules were added to existing modules, the willingness to purchase a paid subscription increased to 52.4%, while 47.6% remained unprepared to pay. Thus, adding new modules increased the percentage of respondents willing to purchase a paid subscription by 7.6%.

The following amount respondents are ready to spend on a subscription per year: 400 rubles — 44.8%, 800 rubles — 13.3%, not ready

to pay for a subscription — 38.1%, less than 400 rubles — 3.8%.

One of the survey questions was related to obtaining the respondents opinion on this mobile application development, we also found it necessary to cite the most interesting statements in our study. Respondents expressed their wishes and recommendations to the developers to improve the quality and attractiveness of using Homila AI m mobile application, some of them are given below.

Respondent 1: *It's a very interesting app, still really small functionality, but the app definitely has potential.*

Respondent 2: *The design is strict, I would like a more friendly design, maybe with pictures.*

Respondent 3: *About the subscription I can say the following. Suppose I got pregnant, bought the pro version, but it's for 1 year. But I don't need a year, 9 months is important to me. Either the application should be further developed so that a young mum could keep notes there, could also see what is normal for the baby, and what is clearly abnormal, or after pregnancy is over, the application should advise me to switch to another one from your company, where I can continue to receive help, now as a young mum.*

Respondent 4: *Subscription for the period of pregnancy. It is better to add more app for the development of children from 1 month to 1 year.*

Respondent 5: *There are a lot of free apps like this now, very attractive, convenient and informative. I am pregnant now and I am using one of them. What I would not like to see in such an app is a check of my risk level, because even without that there is cause for concern, and when the app gives an increased risk based on few data, it is even more worrying. Plus, I couldn't measure my blood sugar and blood pressure and I couldn't measure my heart rate if I didn't have a smartwatch. So you need some other means of getting information (tonometer, thermometer, etc) to use the app.*

Overall, more than 90% of survey responses were positive about the mobile app developed and more than 60% of respondents were willing to pay a paid annual subscription to use the mobile app during pregnancy.

CONCLUSION

Analysis of existing information and digital products in the Republic of Uzbekistan has shown a certain maturity of the health care system in terms of its digitalisation, nevertheless, a number of studied developments, especially using artificial intelligence technologies, remain unclaimed or do not work to the fullest extent, which requires further study and support from the state.

The developed software product using artificial intelligence technologies based on machine learning is an alternative way to prevent maternal complications during pregnancy and can be used both by nurses and directly by women of reproductive age as an independent diagnosis and vigilance towards their maternal health.

The survey showed readiness to use the mobile application during pregnancy, with more than 50% of them ready to pay a paid subscription in order to use it.

ADDITIONAL INFORMATION

Author contribution. Thereby, all authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study.

Competing interests. The authors declare that they have no competing interests.

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