IoT and Deep Learning Enabled Smart Solutions for Assisting Menstrual Health Management for Rural Women in India: A Review

Revathi Kesavan [a], Naveen Palanichamy [b,*], Tamilselvi Thirumurugan [c]

[a] *Department of Artificial Intelligence and Data Science, Dhanalakshmi College of Engineering, Manimangalam, Chennai, India*
[b] *Faculty of Computing and Informatics, Multimedia University, Selangor, Malaysia*
[c] *Department of Computer Science and Engineering, SRM Institute of Science and Technology, Ramapuram Campus, Chennai, India*
Corresponding author: *p.naveen@mmu.edu.my*

Abstract— **A global medical issue, primarily raised in underdeveloped nations, is inappropriate Menstrual Hygiene Management (MHM) among teenage girls. Menstrual hygiene is a global concern because there are over 0.6 billion teenage females (about 8% of the population). The Asian and African continents are home to over 80% of these teenagers. Throughout, 355 million girls and women in India have periods. However, MHM causes discomfort and a lack of respect for millions of women all over the country. In alignment with today's technologies like cloud computing, artificial intelligence (AI), and Internet of Things (IoT), the MHM can be handled effectively. A quantitative survey was carried out among 184 random volunteers aged 18-22 to reveal the current status of MHM in India. The result of the survey confirmed that 72.8% of girls encountered stress during their period, 45% of them were unaware of hygiene products to be used while in the menstruation cycle, 65.2% of them used sanitary pads, and 57.6% of them received disrespectful treatments. This work aims to empower women with the MHM by facilitating knowledge on the menstrual cycle and guiding them about safe-to-use products and disposal strategies in home, work, or community places with the help of technological advancements. Further, introduce a simple friendhood discussion forum through an intelligent chatbot like "Sirona, " a chatbot built over Whatsapp that facilitates a complete ecosystem for MHM.**

Keywords—**Deep learning; intelligent agent; internet of things (IoT); menstrual hygiene; regulatory monitoring; wireless sensors.**

I. INTRODUCTION

The World Health Organization defines an adolescent as someone between 10 and 19 years old. Adolescence, characterized by the kid's growth and progress, is the era between adulthood and childhood. The child develops physically, mentally, and biologically throughout this time. A woman's most significant biological turning point in her development is her menarche, which marks the beginning of her reproductive stage. Generally speaking, menarche occurs between 12 and 13, the typical age among populations. Unfortunately, the situation gets worse for females as a result of their lack of preparation for and control of their periods, as well as their shyness and embarrassment. Even though menstruation is a natural occurrence, it is nonetheless frowned upon in Indian culture since it is viewed as filthy and disgusting [1], [2]. Women have created their unique coping mechanisms to deal with this time. Due to individual choices, resource availability, cultural practices, beliefs, economic position, educational attainment, and general familiarity with menstruation, these solutions differ significantly between cultures [3]. Menstrual hygiene practices have a significant impact on health and, if neglected, can result in reproductive tract infections (RTI), toxic shock syndrome (TSS), along with other vaginal disorders [4]–[6].

Global attention to MHM has recently focused on the need for privacy and dignity, ending the shame and silence, ensuring safe and effective MHM absorbents are available, and enhancing schools' Water, Sanitation, and Hygiene

(WASH) environment. The latter features separate bathrooms for women, water, cleaning supplies, and secure trash disposal. Due to extreme riches and poverty as well as gender-related inequality, India is a nation of contrasts, and this diversity is reflected in the wide range of health and social indices among girls and women. Only 68 million of the 113 million teenage females attend school, and inadequate MHM practices and social prejudices are considered obstacles to their attendance [7].

One sign of a woman's general well-being is her menstrual cycle, which should be regular. In addition to interfering with one's personal and professional life, abnormal cycles with irregular and excessive bleeding call for assessment because they could have a significant adverse effect on one's general and reproductive health in the future. According to numerous studies, stress is one of the main causes of irregular menstrual cycles [8]. Therefore, this study aims to compare the perceived stress level and how it affected Indian women's menstrual cycles. Further, this research intends to analyze MHM's state-of-the-art practices and modern technologies.

II. MATERIALS AND METHOD

The past efforts by various researchers in bringing effective MHM is summarized below.

A. Need for MHM

Two case studies are provided below to highlight the importance of MHM in India.

1) Case 1: A 12-year-old seventh-grade student in a Tamil Nadu school recently committed suicide as a result of being teased about her period. Her mother claims that the beginning of her periods occurred when she was handed a dusting cloth to use as a pad in class. She allegedly had to leave the classroom after her clothing became soaked with blood. According to the suicide note, the next day, she could not take the humiliation and killed herself as a result of the teacher abusing and harassing her in front of the class [9]

2) Case 2: Manisha, a 20-year-old woman from Uttar Pradesh, used to feel guilty about openly disposing of sanitary waste. This occasionally resulted in disputes between neighbors over "whose rubbish it is." However, Manisha, being the feisty one, began requesting improved hygiene at home. In an argument with her father, she persuaded him to add a bathroom to their house. At first, he did not take that seriously. However, after highlighting the necessity of having a bathroom at the house and its hygienic benefits. He finally constructed one. Manisha also constructed a trench in the farmland owned by her family to store sanitary waste so she would not leave menstrual waste lying around [10].

In the first case, the lack of knowledge on menstruation, poor treatment, and inadequate access to sanitary products are brought to the notice. To avoid such loss in the future, as described in case 2, all must cooperatively approach the issue with a broader sense by neglecting ignorance or wrong beliefs. To safeguard our female community, we must support, understand, and respect by providing MHM over the home, workplace, community gathering, etc.

B. Research Studies in Support of MHM in Place

The researchers [3]–[6] investigated the practices and challenges faced by the Indian girls/women on MHM. The author revealed the ignorance of the girls in the awareness of the menstrual process, products, handling, and disposal of the same in the environment. From menstruation phases to the availability of various sanitary pads until their safe disposal methods are discussed in the work.

A deep study on preparedness for MHM in schools in India was conducted [11], and valuable action-level policies to improve the current status are discussed in the article. The author also suggested coming out of wrong beliefs in custom. The male's role in developing a dignified system towards females in handling their MHM is also elaborated. Likewise, another author [12] carried out a systematic study on MHM to portray the facilities in Indian schools for girls. The paper highlights the need for increased awareness, improved wash facilities, life skills education, and public health procedures on MHM.

The authors of the article [8] identified that there exists a strong dependency between the adolescent girl's premenstrual symptoms and stress. The detailed survey reveals that stress is a significant factor that impacts one's menstrual cycle. According to the study by the researchers [13], there is a clear link between the delay in getting enough sleep and feeling frustrated more often while under lockdown. These two factors both have an impact on premenstrual syndrome intensity and the irregularities of monthly cycle onset, which is a sign that the pandemic is harming women's reproductive health.

A detailed study was carried out to reveal a promising association between stress and menstrual cycle disturbance conducted over 53 female students. Also, the authors found that there exists a strong correlation between stress and menstrual disorders [14]. In the article [13], an attempt is made to establish the relationship between stress and menstrual cycle disorder. The menstrual cycle gets the body ready for conception. The uterus is told to lose its lining by the hormones in menstruation. Menstruation, the follicular phase, ovulation, and the luteal phase are the four stages of the menstrual cycle. Premenstrual syndrome (PMS) and painful or heavy periods are common menstrual issues. Hormonal changes during the premenstrual period set off many brain processes that cause symptoms that are both physical (pain, swelling, etc.) and psychological (sour mood, anxiety, etc.). Likewise, the resultant survey of [15] says that the PMS is purely a cognitive-personality factor of individuals while assessing their performance against some stressors.

C. Role of IoT in MHM

The variety of wearable sensors and its significance in detecting menstrual cycle with detailed description is enlisted [16]. The author [17] gave a brief overview of the general application of IoT solutions in healthcare, including everything from early wearable sensor-based health monitoring systems to the most recent developments in fog/edge computing for smart health. Smart healthcare platforms are frequently made able to handle near the actual applications by combining Cloud with IoT infrastructures. This is done by processing and applying AI to the massive amounts of data produced by wearable sensor networks.

An IoT based BBT monitoring system using NTC thermistor-type temperature sensor is delivered [18]. They utilized arduino as the development board and data collected from the sensor handled by ThingSpeak which is a cloud platform for IoT applications. A smart ovulation detector which relies on Basal Body Temperature (BBT) is designed [19]. The BBT charts are a tried-and-true method for determining when a menstrual cycle begins and whether ovulation has taken place. It is the simplest and least expensive technique. An IoT device to monitor the BBT based on abdomen thickness to predict women's ovulation cycle is developed [20]. A successful and eco-friendly IoT-based napkin dispenser design for realization is delivered [21]. The impact of mobile applications and their usage pattern for achieving self-tracking of the menstrual cycle is presented [22]–[25].

D. Role of Machine Learning in MHM

Various machine learning algorithms are attempted to predict menstrual abnormalities [26]. Among other classifiers like naïve Bayes, k-nearest neighbor (k-and support vector machine (SVM), the logistic regression predictive model provided better accuracy at 88%. Blood loss with vaginal or cesarean deliveries that exceeds 500 ml is referred to as postpartum hemorrhage (PPH). An effective machine learning model to predict PPH is brought [27]. Fuzzy output values between 0 and 1 indicate medium-level PPH (MPPH), 1 represents a patient state with normal level PPH (NPPH), and 0 indicates a patient condition with high-level PPH (HPPH). Using IoT structure, neighboring physicians or nurses are contacted for medical assistance based on the sensitivity of the expected values.

A linear mixed and probability-based machine learning model is developed to predict fertile window and menstruation [28]. The authors conducted a cohort study on informed consent at the International Peace Maternity and Child Health Hospital in Shanghai, China. In order to collect the physiological data like BBT and heart rate (HR), used an ear thermometer and Huawei band 5 were used, respectively. The established system projected the menses with an accuracy of 89.6% and the fertile window with an accuracy of 87.46%. A hierarchical and generative model to predict cycle lengths through accounting for the self-tracking artifacts of users to benefit users, researchers of this domain, and mobile health application developers are brought to notice [29]. Based on data collected from mobile health self-tracking cycles, the prediction models for the onset of the following menstrual cycle are developed [30]. Physiological menstruation patterns must be separated from tracking habits to create predictive models, even though mobile users may choose to avoid tracking. The design and insights of building a lightweight mobile application for older people are analyzed with great interest [31]. A detailed process to fine-tune the application design and technical notes are gathered [32], [33].

E. Research Objectives

The primary objectives of this research are as follows:
- To evaluate an awareness of Menstrual Hygiene Management (MHM) in rural areas of India

- To design a cost-effective IoT solution to track the menstrual cycle by integrating appropriate physiological sensors
- Facilitate a smart design of sanitary disposers. This also preserves the environment.
- To ensure prediction accuracy by building an effective machine learning model in detecting the menstrual cycle in advance.
- To bring an intelligent and friendlier interactive agent to support the female community throughout their menstrual cycle and guide them through their doubts with machine learning to improve the performance index and to obtain remote access control over the system design.

The suggested system aims to create a low-cost, low-energy model that uses an Internet of Things (IoT) based sensory circuit to create an efficient model for routinely monitoring physiological symptoms and anticipating women's periods. It is planned to be implemented through various phases listed and explained below.

F. Method to Evaluate MHM

The method used to evaluate MHM awareness is a survey. In connection with that, a questionnaire is prepared. The one-to-one interview is exercised over the 64 girls, with an age limit of 19-22, residing in a rural region called 'Varadharajapuram' in Chennai, Tamil Nadu. Also, an online survey was conducted among 100 students. The questionnaire involves both qualitative and quantitative questions, and it is designed in a way to derive answers to the following facts:
- The cause of the stress and its level
- Societal treatment over time
- Menstrual Products like menstrual cups, pads, tampons, etc.,
- Disposal methods in practice
- Readiness in admitting technological advancements in MHM
- Awareness of applications on MHM

G. An IoT Prototype for Tracking Period and Disposal Unit of Period Wastage

Based on past efforts, BBT is accounted as the primary vital indicating the menstrual cycle. BBT will vary according to abdomen thickness; hence, a flex sensor is combined with a temperature sensor to retrieve accurate BBT. Heart rate variability is another important signal that helps to determine the menses in advance. Together with the relevant sensors already mentioned, the candidate will receive a functional prototype for regulatory monitoring of their biological states. The development board, which is the system's central component, will be chosen. The Arduino Uno is the microprocessor of choice for the suggested model. As shown in Fig. 1, the design will be completed when the sensors are integrated in their proper locations and additional parts, including the charging and communication units, are added.

The present-day sanitary napkin disposal method is known as "Ashuddhi-Nashak." It is seen in Fig. 2. This system has two apertures or covers. The top aperture is used to toss the used napkin. When a newspaper is inserted, fire is sparked first from the bottom aperture. The napkin also fires as the newspaper does. At the bottom, ash is collected and can be

manually discarded. This approach resolves the issue of soil contamination; however, the air pollution problem is not addressed. This mechanism emits carbon dioxide gas, which pollutes the atmosphere.

The suggested method for disposing of sanitary napkins attempts to lessen overall soil and air pollution. The system is operated using solar energy. After turning on the sanitary disposal system, a speech system tells the user to place the serviette within the assigned tray. The different views of the proposed napkin disposer are captured in Fig. 3.

Fig. 1 Proposed vital monitor for period tracking

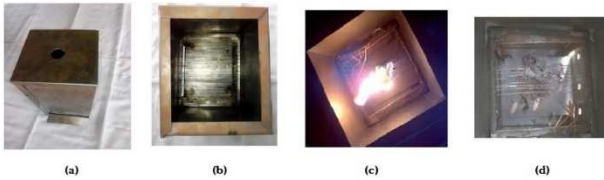Fig. 2 Existing sanitary napkin disposer solution

Fig. 3 Proposed sanitary napkin disposer presenting a) An overall view b) Spider coil furnace with no napkin c) Burning napkin, and d) Burnt ashes. [21]

The IR sensor detects the napkin when it is placed in the tray and alerts the raspberry pi. Turning on the spider coil is instructed by the raspberry pi. The sanitary towel is reduced to ashes by the spider coil. The toilet's drain can be used to flush the ash that has accumulated. This device emits carbon dioxide, which a CO2 filter absorbs. It has been noted that burning napkins results in air pollution and that tossing them outside creates an unclean and filthy environment. Although the current approach (Ashuddhi-Nashak) has successfully reduced soil pollution, it has not been as successful in reducing air pollution. Additionally, it is not a compact system, making interior application impractical. This system can be used in toilets because it is compact, which makes disposing of napkins simple.

H. Deep Learning Model for Predicting Menstrual Cycle

To attain an optimal result, the proposed work is designed to employ a deep neural network (DNN) which comprises of

pre-training and testing phases of its own. In its training phase, a deep belief network facilitates an inherent infrastructure and regular feed forward design which accepts input and processes through several hidden or multiple layers of choice. It allows the method to initiate the necessary based on the hidden units that supply system conviction. In addition, the restricted Boltzmann machine (RBM) is exercised to overcome further issues. The stochastic hidden and recognized units are the typical layers of RBM, belonging to the Markov random field, as in Fig. 4.
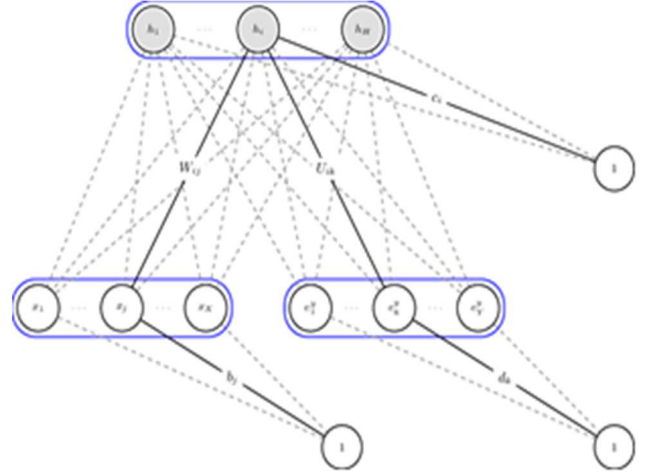

Fig. 4 Structure of RBM

The visible units are created at the initialization step. A heterogeneous RBM is organized and adopts a multilayer model during the training operation. By rearranging current weights and biases, the RBM layers' units' habits are applied. The fundamental back-propagation (BP) approach is used in the tuning phase. Each time RBM is to be in a specific condition or state. The state constitutes the neuron values in the hidden and visible layers named v and h, respectively. The following joint distribution given in equations 1-6 describes the likelihood of observing a specific state of v and h:

$$p(v, h) = \frac{1}{Z} e^{-E(v,h)} \qquad (1)$$

$$Z = \sum_{v,h} e^{-E(v,h)} \qquad (2)$$

$$p(h|v) = \prod_i p(h_i|v) \qquad (3)$$

$$p(v|h) = \prod_i p(v_i|h) \qquad (4)$$

$$p(h_j = 1|v) = \frac{1}{1+e^{(-(b_j+W_j v_i))}} = \sigma\left(b_j + \sum_i v_i W_{ij}\right) \quad (5)$$

$$p(v_i = 1|h) = \frac{1}{1+e^{(-(a_i+W_i h_j))}} = \sigma\left(a_i + \sum_j h_j W_{ij}\right) \quad (6)$$

The hidden layer's activations can be added to other models as useful features to improve performance, which is one of RBM's benefits. It is quicker than a typical Boltzmann machine because of the connection restrictions between nodes. Also, it is sufficiently concise and effectively computed to encode any form of distribution.

I. Development Platform for Chatbot

A chatbot is computer software that simulates human communication by interpreting user inquiries using natural language processing (NLP) and artificial intelligence (AI).

There are primarily three types of bots that one can construct, including:

1) Rule-based Chatbots: Rule-based bots operate according to a predetermined conversation flow that enables the bot to proceed rationally in response to human inputs and selections. Users go through the conversation flow by selecting items from the menus, carousels, and buttons and providing answers to questions. Rule-based bots are more straightforward to create and more user-friendly for consumers to operate. Users cannot ask inquiries on their behalf; instead, they can only provide information whenever the bot specifically requests it (such as contact information or information on the use case).

2) AI Chatbots: AI chatbots use natural language processing to comprehend the structure of sentences and then analyze that knowledge, gradually improving their ability to respond to the question.

3) Hybrid Chatbots: As the name implies, the hybrid chatbot combines live chat capabilities with the finest rule-based and AI to offer a more fabulous client experience.

Creating a chatbot has several components, including a strategy, dialogue flow, technologies, devices, procedures, reports, and more. In this section, Table I summarizes the most powerful platforms in practice for building a chatbot.

TABLE I
MOST PROMISING CHATBOT DEVELOPMENT PLATFORMS

Platform	Features	Merits	Demerits
WotNot	• Uses drag and drop interface to build a chatbot without coding	• Easy to use • Supports a variety of mediums, including SMS, websites, Messenger and WhatsApp • Allows unlimited conversations	• Allows only 10 bots per account
Intercom	• Offer specialized chatbots for use in sales, marketing, and customer support use cases	• Allows quicker design without coding • Facilitates proactive conversation	• The complex user interface (UI) increases the level of difficulty in design • No free version
Drift Chatbot	• Without the use of any forms, the bot qualifies website visitors and promotes discussions with leads. Additionally, it locates the appropriate sales representative and plans a meeting for them	• Allows wide range of integration • Produces quick responses through 'Drift Automation'	• Expensive • Push alerts used by the mobile app to clarify talks are not very effective
LivePerson	• A good platform for creating, deploying, and optimizing AI-powered chatbots. The ability to use advanced analytics for ongoing optimization and in-the-moment intent recognition is one of its highlights	• Convenient to use • Supports a variety of mediums, including SMS, websites, Messenger and WhatsApp • Allows unlimited conversations	• No free trial • Reporting is bit difficult
Bold360	• Using patented NLP technology, it is possible to comprehend consumers' intentions without the use of keyword matching	• Robust platform handles human handoff quickly	• Ineffective pricing with outdated UI • Lacks aesthetic appeal

III. RESULTS AND DISCUSSION

A. Demographic Analysis of MHM

The demographic analysis is crucial as it provides information that may be utilized to make wise decisions in various settings, including industry, government, and social services. Age, ethnic background, gender, marital relationship, and level of education are a few examples of demographic information. Making decisions requires knowledge of a population's features and potential future changes, which this information provides. The research results were obtained by distributing questionnaires to 184 volunteers. Based on the survey, it was found that 72.8% of volunteers experienced stress. The age distribution that filled out the most questionnaires was 19-22 years, and 42.9 % of respondents were 22.

Among volunteers, 65.2% chose and used sanitary pads as primary hygiene products in their menstrual cycle. Out of the total participants in the survey, nearly 57.6 % realized bad treatment because of the customs and cultural practices.

Around 75% of them are unaware of the mobile-based applications supporting MHM. Most importantly, 83.7% of them are willing or looking for promising services and products to facilitate effective MHM in the future. The resultant of the analysis is captured and presented in Table II.

TABLE II
DEMOGRAPHIC ANALYSIS ON VOLUNTEERS

Demographic Factors	Indicators	Total Participant	Percentage
Gender	Female	184	100%
Age	19	45	24.5%
	20	20	10.9%
	21	40	21.7%
	22	79	42.9%
Stress	Yes	134	72.8%
	No	50	27.2%
Societal Respect	Good	78	42.4%
	Bad	106	57.6%
Product Awareness	Pads	120	65.2%
	Tampons	22	11.9%
	Menstrual	32	17.4%
	cups	10	0.5%

	Others		
Disposal method	Satisfactory	44	23.9%
	No Satisfactory	140	76.1%
Readiness for technological advancements in MHM	Yes	154	83.7%
	No	30	16.3%
Have they ever experienced mobile applications on MHM?	Yes	46	25%
	No	98	75%

In exploring stress levels in individuals on menstruation, the causes for it are identified as nervousness about strain, pain, fear about travel, and associated health ailments like vomiting, mood swings, etc. The distribution scale of stress causes in MHM is well demonstrated in Fig. 5. From the results. It is found that anxiety about strain contributes more (approximately 62%) to the cause of stress than to period pain, engaging in other activities, and health ailments.

B. Performance Analysis of Deep Learning Practice

Using the Tensor Flow 2.0 execution environment, the suggested deep learning model's effectiveness is evaluated. Google created it as an open-source project. Its accessibility has led developers to favor it as a solution. Mean absolute error (MAE) and root mean square error (RMSE) are performance measurements used to evaluate the proposed deep learning model. The mathematical expression for RMSE and MAE is captured in equations (7) and (8), respectively.
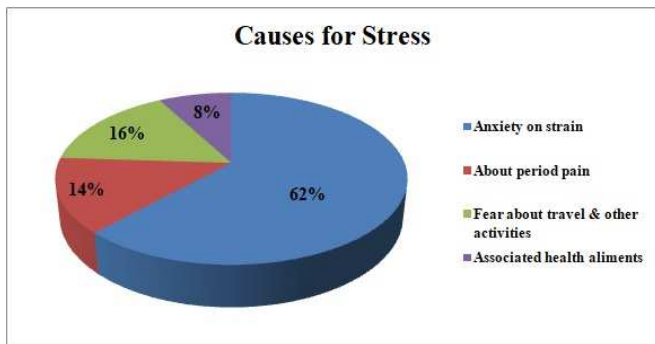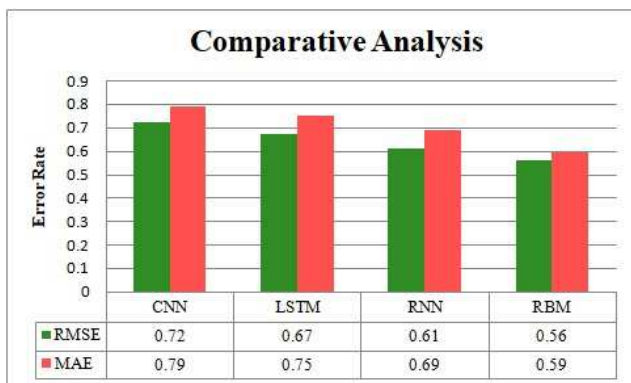

Fig. 5 Cause analysis of stress

Fig. 6 Performance analysis of deep model

Comparisons are made between the proposed model (RBM) and significant machine learning methods like CNN, LSTM,

and RNN. The primary objective is to assess the degree to which the model's predictions agree with the observed values. As such, a higher RMSE is seen as "bad," whereas a lower RMSE is regarded as "excellent". The residual in the formula represents the discrepancy between the observed and projected values. The total squared residuals make up the mean squared error (MSE). By taking the square root of the RMSE, the measure is then reset to the scale of the response variable. The comparative analysis is best illustrated in Fig. 6.

The findings unequivocally demonstrate that the suggested deep model has a relatively low error rate ranging from 0.5 to 0.6 at most.

C. Existing Mobile Applications

The application launched by India with a motive to track is listed below.

1) Sirona was designed with a focus on attaining three objectives: tracking the period, checking the fertility window for conception, and avoiding pregnancy. It is a chatbot that is built upon the WhatsApp account on +91971886644. Upon providing the necessary details, one can communicate with "Sirona," as in Fig. 7. The noteworthy mobile applications developed and utilized internationally to track female menstrual cycles are listed below.
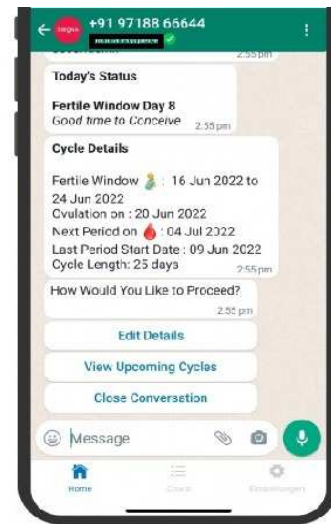

Fig. 7 Screenshot of Sirona

2) Flo is a smart tracker designed to track menstrual, ovulation, and fertile days. Works in coordination with InData Labs for managing and processing the data delivered by wearable's of customers.

3) PD Lover–a mobile application aimed to track period and physical changes which will occur over that period.

The comparison of the above-mentioned applications targeting MHM is best presented in Table III.

TABLE III
PERFORMANCE ANALYSIS OF APPLICATIONS ON MHM

Application	Advantages	Disadvantages
Sirona	Available in Google play store for usage. It is also accessed through from one's WhatsApp account	Highly accommodated with contents about MHM products and its sales forum
Flo	Globally, Flo is used by more than 250 million individuals	No space for MHM practices and products,

Application	Advantages	Disadvantages
	because of its features like precise predictions, ensuring privacy and medical creditability	instead acts as pregnancy assistance
PD Lover	For females who experience both regular and irregular periods, the app is incredibly useful with notifications and informed choices accessing though their Facebook account	Seeks high level of customization while generating responses to its customers

IV. Conclusion

The research aims to uncover the status of MHM practices in India and is conducted through a survey. The result protects the consumer's readiness for effective MHM with the help of modern technologies like AI, IoT, and Data Analytics. The study presented a smart device for monitoring the menstrual cycle and a friendly disposal unit. A further deep learning model (RBM) is proposed for predicting the menstrual cycle in advance by accounting features like BBT, mucus, and others. It is about to produce a lower error rate than machine learning models like CNN, LSTM, and RNN. The error rate lies between 0.5-0.6. Moreover, this study introduces mobile-based applications developed to support MHM, like Sirona.

Due to time constraints, the study was conducted over a reasonable age group of limited volunteers. It plans to evaluate and assess a promising number of volunteers covering different regions through trusted online survey methods. The applications realized in practice necessitate an account on a social platform like Facebook or WhatsApp. No application offers adequate knowledge of MHM and real-time solutions with smart monitoring devices. Further, it is recommended to build a virtual assistant by incorporating readings from the smart device, which predicts the menstrual cycle using the RBM, an affordable choice for highly novice users.

References

[1] S. Nagar and Kh. R. Aimol, "Knowledge of Adolescent Girls Regarding Menstruation in Tribal Areas of Meghalaya," Studies of Tribes and Tribals, vol. 8, no. 1, pp. 27–30, Jul. 2010, doi:10.1080/0972639x.2010.11886610.

[2] A. Dasgupta and M. Sarkar, "Menstrual hygiene: How hygienic is the adolescent girl?," Indian Journal of Community Medicine, vol. 33, no. 2, p. 77, 2008, doi: 10.4103/0970-0218.40872.

[3] S. B. Thakre, S. S. Thakre, M. Reddy, N. Rathi, K. Pathak, and S. Ughade, "Menstrual hygiene: knowledge and practice among adolescent school girls of Saoner, Nagpur District," Journal of Clinical and Diagnostic Research, vol. 5, no. 5, pp. 1027–1033, Oct. 2011.

[4] D. Sapkota, D. Sharma, H. P. Pokharel, S. S. Budhathoki, and V. K. Khanal, "Knowledge and practices regarding menstruation among school going adolescents of rural Nepal," Journal of Kathmandu Medical College, vol. 2, no. 3, pp. 122–128, Mar. 2014, doi:10.3126/jkmc.v2i3.9962.

[5] A. Khanna, R.S. Goyal, and R. Bhawsar, "Menstrual Practices and Reproductive Problems," Journal of Health Management, vol. 7, no. 1, pp. 91–107, Apr. 2005, doi: 10.1177/097206340400700103.

[6] R. Kaur, K. Kaur, and R. Kaur, "Menstrual Hygiene, Management, and Waste Disposal: Practices and Challenges Faced by Girls/Women of Developing Countries," Journal of Environmental and Public Health, vol. 2018, pp. 1–9, 2018, doi: 10.1155/2018/1730964.

[7] A. M. van Eijk et al., "Menstrual hygiene management among adolescent girls in India: a systematic review and meta-analysis," BMJ Open, vol. 6, no. 3, p. e010290, Mar. 2016, doi: 10.1136/bmjopen-2015-010290.

[8] R. Singh, R. Sharma, and H. Rajani, "Impact of stress on menstrual cycle: A comparison between medical and non medical students," Saudi Journal for Health Sciences, vol. 4, no. 2, p. 115, 2015, doi:10.4103/2278-0521.157886.

[9] Arunima Bhattacharya Bhattacharya, "Tamil Nadu: 12-Yr-Old Commits Suicide After Alleged Humiliation By Teacher For Menstrual Stains," The Logical Indian.

[10] UNICEF, "A young star promoter of menstrual health – at home and to multiple generations Meet the menstruation health champion from Uttar Pradesh."

[11] S. Sharma, D. Mehra, N. Brusselaers, and S. Mehra, "Menstrual Hygiene Preparedness Among Schools in India: A Systematic Review and Meta-Analysis of System-and Policy-Level Actions," International Journal of Environmental Research and Public Health, vol. 17, no. 2, p. 647, Jan. 2020, doi: 10.3390/ijerph17020647.

[12] F. H. Taufiq, H. Hasnawi, and R. Hidayat, "Stress Induces Menstrual Cycle Disturbance Among Female Students in Faculty of Medicine Universitas Sriwijaya," 2019. [Online]. Available: www.bioscmed.com

[13] K. C. Chung et al., "The Influence of Menstrual Cycle and Androstadienone on Female Stress Reactions: An fMRI Study," Frontiers in Human Neuroscience, vol. 10, Feb. 2016, doi:10.3389/fnhum.2016.00044.

[14] A. Dhawan and J. Hernole, "Effect of Perceived Pandemic Stress and Sleep Variation on Menstrual Cycle Occurrence, its Severity and Premenstrual Syndrome: A Cross Sectional Study," Journal of Women's Health and Development, vol. 03, no. 04, 2020, doi:10.26502/fjwhd.2644-28840052.

[15] T. Matsumoto, M. Egawa, T. Kimura, and T. Hayashi, "A potential relation between premenstrual symptoms and subjective perception of health and stress among college students: a cross-sectional study," BioPsychoSocial Medicine, vol. 13, no. 1, Oct. 2019, doi:10.1186/s13030-019-0167-y.

[16] B. M. Goodale, M. Shilaih, L. Falco, F. Dammeier, G. Hamvas, and B. Leeners, "Wearable Sensors Reveal Menses-Driven Changes in Physiology and Enable Prediction of the Fertile Window: Observational Study," Journal of Medical Internet Research, vol. 21, no. 4, p. e13404, Apr. 2019, doi: 10.2196/13404.

[17] L. Greco, G. Percannella, P. Ritrovato, F. Tortorella, and M. Vento, "Trends in IoT based solutions for health care: Moving AI to the edge," Pattern Recognition Letters, vol. 135, pp. 346–353, Jul. 2020, doi: 10.1016/j.patrec.2020.05.016.

[18] M. S. M. Yazed and F. Mahmud, "The development of IoT based BBT charting and monitoring using ThingSpeak," AIP Conference Proceedings, 2017, doi: 10.1063/1.4968341.

[19] S. Thiyagarajan and P. Parthiban, "Smart Basal Body Temperature Monitoring and Indication Of Ovulation Using IoT," International Research Journal of Engineering and Technology, 2017, [Online]. Available: www.irjet.net

[20] R. Prasannan and G. Sarath, "IoT based Device for Fertility Monitoring," in Fifth International Conference on Communication and Electronics Systems (ICCES 2020), 2020, pp. 813–817.

[21] K. Samba Siva Rao, A. Dhineshkumar, A. Jeeva, C. Sathish, and T. Sujith Kumar, "Iot Based Intelligent Sanitary Napkin Disposer," Advances in Natural and Applied Sciences, vol. 11, no. 10, pp. 32–40, Aug. 2017.

[22] E. Wartella, V. Rideout, H. Montague, L. Beaudoin-Ryan, and A. Lauricella, "Teens, Health and Technology: A National Survey," Media and Communication, vol. 4, no. 3, pp. 13–23, Jun. 2016, doi:10.17645/mac.v4i3.515.

[23] R. J. Shaw et al., "Mobile health devices: will patients actually use them?," Journal of the American Medical Informatics Association, vol. 23, no. 3, pp. 462–466, Jan. 2016, doi: 10.1093/jamia/ocv186.

[24] I. Vaghefi and B. Tulu, "The Continued Use of Mobile Health Apps: Insights From a Longitudinal Study," JMIR mHealth and uHealth, vol. 7, no. 8, p. e12983, Aug. 2019, doi: 10.2196/12983.

[25] A. A. Shea and V. J. Vitzthum, "The extent and causes of natural variation in menstrual cycles: Integrating empirically-based models of ovarian cycling into research on women's health," Drug Discov Today Dis Models, vol. 32, pp. 41–49, 2020, doi:10.1016/j.ddmod.2020.11.002.

[26] Y. D. S, R. A, and V. M, "Machine Learning based Comparative Analysis for Menstrual Abnormalities," International Research Journal of Engineering and Technology (IRJET), vol. 7, no. 8, pp. 1721–1725, Aug. 2020.

[27] V. D. A. Kumar et al., "A novel solution for finding postpartum haemorrhage using fuzzy neural techniques," Neural Computing and

Applications, vol. 35, no. 33, pp. 23683–23696, Jan. 2021, doi: 10.1007/s00521-020-05683-z.

[28] J.-L. Yu et al., "Tracking of menstrual cycles and prediction of the fertile window via measurements of basal body temperature and heart rate as well as machine-learning algorithms," Reproductive Biology and Endocrinology, vol. 20, no. 1, Aug. 2022, doi: 10.1186/s12958-022-00993-4.

[29] K. Li, I. Urteaga, A. Shea, V. J. Vitzthum, C. H. Wiggins, and N. Elhadad, "A generative, predictive model for menstrual cycle lengths that accounts for potential self-tracking artifacts in mobile health data," Feb. 2021.

[30] K. Li, I. Urteaga, A. Shea, V. J. Vitzthum, C. H. Wiggins, and N. Elhadad, "A predictive model for next cycle start date that accounts for adherence in menstrual self-tracking," *Journal of the American Medical Informatics Association*, vol. 29, no. 1, pp. 3–11, 2022.

[31] C. Y. Seek, S. Y. Ooi, Y. H. Pang, S. L. Lew, and X. Y. Heng, "Elderly and Smartphone Apps: Case Study with Lightweight MySejahtera," Journal of Informatics and Web Engineering, vol. 2, no. 1, pp. 13–24, Mar. 2023, doi: 10.33093/jiwe.2023.2.1.2.

[32] A. A. Zaveri, R. Mashood, S. Shehmir, M. Parveen, N. Sami, and M. Nazar, "AIRA: An Intelligent Recommendation Agent Application for Movies," Journal of Informatics and Web Engineering, vol. 2, no. 2, pp. 72–89, Sep. 2023, doi: 10.33093/jiwe.2023.2.2.6.

[33] W.-X. Ong, S.-B. Ho, and C.-H. Tan, "Enhancing Migraine Management System through Weather Forecasting for a Better Daily Life," Journal of Informatics and Web Engineering, vol. 2, no. 2, pp. 201–217, Sep. 2023, doi: 10.33093/jiwe.2023.2.2.15.