

PurpleAid: An mHealth Platform to Combat Health Hazards of Women

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Abstract— Present world is witnessing unprecedented use of mobile technologies in all sectors of everyday life including healthcare and clinical therapies. However, the healthcare of women still lacks sufficient attention from mobile health perspective. Although a number of smartphone applications are available for healthcare of women, all of them focus mainly towards reproductive health like pregnancy and menstruation. In this paper, we present PurpleAid, a complete health support system for women which takes into account possible reproductive and non-reproductive health conditions i.e., conditions unique for women only (e.g., uterine fibroid etc.), affecting men and women differently (e.g., urinary tract infection etc.) and common in both men and women (e.g., heart disease etc.). Our proposed system diagnoses diseases depending on input symptoms given by the users with accurate severity level, provides suggestions for treatment and prevention of the diseases as well as for regular maintenance of fitness. Performance evaluation and usability test results of a prototype implementation show that PurpleAid has emerging potential as a compact user-friendly health support system for women.

Keywords—mobile health; women's health; disease detection; clinical support

I. INTRODUCTION

The health of women deserve special consideration due to both biological and gender-related impacts on health issues as well as widespread sociocultural discrimination against women in the world, especially, in underdeveloped and developing countries [1]. A number of diseases occur only in women including thyroid problems, endometriosis, pelvic inflammatory disease (PID), prolapsed uterus, uterine fibroid, and different types of cancers like ovarian, cervical, breast cancer etc. Moreover, conditions that affect both men and women, such as cardiovascular disease (CVD) including heart attack and stroke, lung cancer, osteoporosis, depression, dementia, diabetes, anemia, urinary tract infection (UTI), sexually transmitted infections (STI) etc. also manifest differently in women [2]. Among these diseases, CVD is one of the leading causes of mortality in women, with over half resulting from coronary artery disease and acute coronary syndromes [3]. Demographic changes like obesity, inactive lifestyle and ageing are going to contribute to a further rise in the rate of diabetes by 2030 [4]. When it comes to female related cancers, annual breast cancer diagnosis stands at an estimated one million cases worldwide, with 410, 00 fatal cases [5]. Because of genetic vulnerability, hormonal fluctuations, stress, internalization coping style and inferior social status,

women during their pregnant years seem to be in the greatest risk of suffering from depression. 21.3% women report a lifestyle prevalence of major depressive disorder compared to only 12.7% of men [6]. Another common case among postmenopausal women is osteoporosis, which increases the risk of fatal hip and spine fractures [7]. Women living in poor and developing countries suffer from even more restricted access to healthcare. A scarcity of skilled healthcare providers, adequate medical facilities and sufficient pharmaceutical formularies result in an increased female morbidity from conditions such as obstetrical fistulas, STIs and cervical cancer that could be easily treated in technologically advanced countries [2].

Considering the severity and healthcare costs of these conditions, preventive healthcare can contribute a lot to reduce the extent of these conditions. Mobile health (mHealth) approaches like cellphone messaging and smartphone applications can offer an easy and affordable solution to the problem of providing quality healthcare facilities to women living in low and middle income countries [8]. The GSM Association estimates that the global mobile penetration rate will be over 70% by the end of 2020 and around 90% of the growth will come from developing regions [9]. An exploratory study shows that mobile phone is highly acceptable as a tool for receiving health information and supporting healthcare through mHealth interventions in the rural Indian context [10]. Besides, women these days appear to be more likely to use smartphones compared to men, with 56% women using a smartphone compared to 51% men. This also translates to a higher rate of women using health related applications, with around 9% women more likely to use these applications compared to 4% men [11]. An US-based survey on two thousand people concluded that women tend to use technology to keep up with their busy lifestyle, with 51% owning apple devices and 93% women keeping their smartphone within their reach [12].

Many of the issues around women's health relate to their reproductive, maternal, genital, breast, and endocrine (hormonal) health, including menstruation, birth control and menopause. However, an undue emphasis on reproductive and maternal health has been a major barrier to ensuring access to good quality health care for all women [13]. This is also reflected in mHealth technologies. Pregnancy and obesity control appear to have the strongest presence among all the applications developed in relation to women's health [14]. Moreover, existing disease detector applications designed to

detect diseases common for both men and women also fail to provide solution for health hazards of women as they do not take into account symptoms of diseases prevalent only in women, such as, heavy menstrual bleeding, menstrual periods lasting more than a week, pelvic pressure or pain, frequent urination, itching or pain in urethra or vaginal opening, extensive or smelly white discharge, pain or swelling in the breasts or underarms etc. while diagnosing probable diseases of the user. In this work, our motivation is to provide a mHealth solution, PurpleAid, to help women handle both reproductive and non-reproductive health hazards. This mobile application can diagnose general as well as women-only diseases with accurate severity level using logistic regression model based on symptoms given by the users and provides personalized suggestions to the users for preventing or reducing the effects of those diseases.

In summary, the contributions of our work are as follows:

- We propose a novel mHealth solution that accurately diagnoses reproductive and non-reproductive health conditions of women taking different kinds of symptoms as inputs from users including those prevalent among women only.
- We calculate the severity level of the diagnosed conditions using logistic regression model.
- We provide suggestions for treatment and prevention of diseases along with nearby hospitals and specialists, if needed. Additionally, we offer regular health and fitness maintaining opportunities for the users.
- We perform a comprehensive performance evaluation of our system by implementing a prototype which shows significant accuracy in diagnosis of conditions and severity level. Besides, the result from a usability test suggests that our system has emerging potential as a user-friendly tool for handling health hazards of women.

II. RELATED WORK

The ubiquitous and frequent usage of mobile technologies has invariably initiated its application to address health priorities giving rise to a new domain known as mHealth. Fourteen types of mHealth initiatives are conducted across the world according to a recent survey on mHealth by WHO [15]. However, usage of decision support system i.e., software that detects diseases based on medical and health information of patients is relatively low (less than 25%) especially in developing regions. Inaccuracy in diagnosis and treatment suggested by the applications are primary causes of this low usage. There are a number of mobile applications (e.g. WebMD [16], Symptomate Symptom Checker [17], iTriage Health [18], Best Android Symptom Checker [19]) that have functions like symptoms checkup and condition matching for detecting diseases. However, none of these existing applications take into account symptoms for diseases that are unique to women or more serious in women or that have different risk factors in women compared to men. Moreover, precise severity level or probability of the detected diseases are

also not shown in these applications. A number of important treatment decisions depend on the severity level of the diseases, such as, hospitalization, starting medication, amount of medicine, measures for quick recovery etc. [20].

Apple store and Google Play Store host various smartphone applications that are developed with the intention of improving women's health. However, reproductive health and weight loss have taken precedence over non-reproductive diseases and conditions among these mobile applications [14]. Menstrual Cycle Calendar Track [21], My Ovulation Calculator [22], My Pregnancy Calculator [23], My Menstrual Diary [24], Period Calendar Cycle Tracker [25], Period and Ovulation Tracker [26] etc. track menstrual cycle for calculating ovulation period. FetalGrowth [27] deals with pregnancy related issues like tracking the growth of the fetus, while Antenatal Appointments [28] helps with medical appointments during pregnancy. Web-based digital health clinic Maven [29] offers services for pregnancy prevention, prenatal and postpartum care by setting up online appointment with nurse practitioners. Moreover, there are also several games concerning care of pregnant women like Pregnant Women Health Care [30], Pregnant Girl Emergency Doctor [31], Pregnant Surgery Simulator [32] etc. Applications like Women's Home Fitness [33], Women's Health 15-Min-Workouts [34] provide exercises for fitness and obesity control whereas Women's Health: 1500 Kalorien [35] provides suggestion for healthy diets. Womens-Health.com [36] forum provides a platform to discuss health issues, menstrual and PMS (pre-menstrual syndrome) problems, weight loss etc. To the best of our knowledge, there is no existing mobile or web application solely designed for women that take various symptoms as inputs from the users to detect diseases with accurate severity level and provide suggestions for prevention and care of those conditions accordingly.

III. OUR APPROACH

In this section, we give an overview of our system, PurpleAid which includes four subsystems to provide an overall health support for women – i) Test ii) Treatment ii) Prevent iii) Maintain Health. The system architecture of PurpleAid is shown in Fig. 1 with all four subsystems.

A. Test

In this subsystem, a user (U) can test whether she has developed or has chances to develop any particular disease based on the symptoms she gives to the system. At first, U gives input of clinical factors (e.g., age, temperature, blood pressure etc.) and various symptoms with corresponding level of severity. The database of our system application contains a huge pool of common symptoms associated with health problems prevalent among both men and women (e.g., headache, back pain, constipation, etc.) as well as women only (e.g. extensive menstrual bleeding, smelly or extensive white discharge, pain and swelling in breasts etc.). Based on the input symptoms and clinical factors, our system diagnoses probable diseases of the user using a logistic regression model.

PurpleAid diagnoses diseases and the severity level i.e., the probability of the user to develop the disease in two steps –

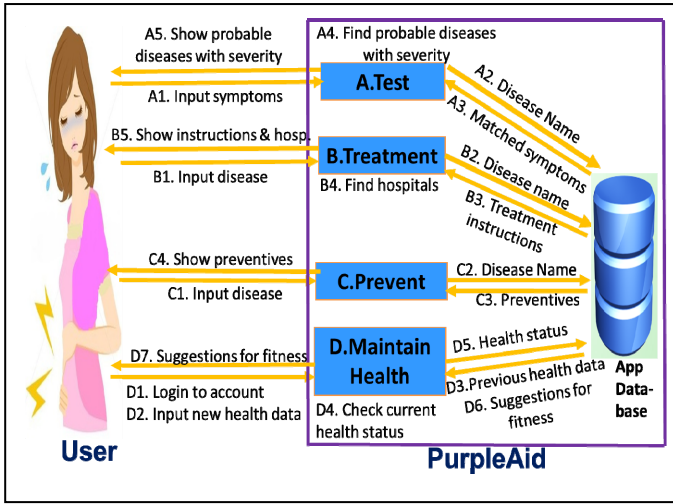


Fig. 1. System architecture of PurpleAid

finding the contribution factor of various symptoms for a particular disease and matching the input symptoms of the user to detect probable disease and the severity level.

1) *Finding Contribution Factors*: Multiple symptoms and clinical factors are related with a disease and those symptoms contribute to different degrees. In studies [41], the contribution factor or weight of a particular symptom S_i is defined as

$$\omega_i = \ln(OR_i),$$

where OR_i is the odds ratio of S_i . Odds ratio denotes the degree to which a specific symptom contributes to a disease. Odds, O of a disease in any particular group of individuals is the ratio of occurrence of that disease to that of its non-occurrence. Hence, odds ratio, OR is the ratio of odds in that group of individuals showing a symptom to that of those who do not show it.

Consider a group of 200 people, among which 100 are affected by a disease X . Suppose that 60 among those 100 people are showing a particular symptom y and the rest are not. Then odds of disease X for the individuals with symptom y is,

$$O(X|y) = 60/40 = 1.5$$

Similarly, suppose that among the rest of the people without disease X , 20 shows symptom y , while 80 does not. Then, odds of disease X for the individuals not showing symptom y is

$$O(X|y') = 20/80 = 0.25$$

Thus, we have, odds ratio associated with symptom y for disease X is,

$$OR = O(X|y) / O(X|y') = 1.5/0.25 = 6$$

Recent medical studies have calculated odds ratio of symptoms and clinical factors associated with a number of diseases. For example, odds ratio of the symptoms of cardiovascular disease can be found in [37]. However, odds ratio of symptoms for several diseases which are unique to

women are yet to found. For our prototype implementation, we collected data from three hospitals to calculate the odds ratio of the symptoms for such disease.

All the symptoms and clinical data related to the diseases are stored in the app database along with respective contribution factors, ω . We note that we need to calculate odds ratio and the contribution factors only once. As such, it does not add significant time and computation overhead for diagnosis of the disease in real time.

2) *Diagnosis of Probable Diseases*: The input symptoms provided by the user U are matched against all the symptoms in the database. For finding probability of diseases, logistic regression model is used by researchers widely [41]. Let λ be the total number of symptoms and clinical factors associated with a disease X , ω_i be the contribution factor of the i^{th} symptom and n_i be the value of the i^{th} symptom, where $n_i \in \{0, 1\}$ and $i = \{1, 2, \dots, \lambda\}$. Then, the regression coefficient, R of the logistic regression model is,

$$R = \sum_{i=1}^{\lambda} \omega_i \times n_i \quad (2)$$

Let P be the probability of developing disease X . We have,

$$R = \ln\left(\frac{P}{1-P}\right)$$

$$\Rightarrow P = \frac{e^R}{1+e^R}$$

The final list of all possible diseases is shown to user U along with their respective probability as percentage. The severity level, L is defined depending on the probability of developing the disease. For better understandability of the users, severity level is shown using color code.

$L = \text{Extreme (Red),}$	where $P \geq 0.66$
$= \text{Medium (Yellow),}$	where $0.66 > P \geq 0.33$
$= \text{Low (Green),}$	where $P < 0.33$

B. Treatment:

In this subsystem, suggestions regarding treatment of various diseases are provided. User can input name and severity level of a disease to see the treatment measures associate with that disease. Besides, user can also get the suggestions immediately after a disease is diagnosed in the test subsystem. Two types of suggestions are provided in our system - i) instructions and medications to handle the disease ii) nearby hospitals and doctors, if needed.

1) *Instructions*: Instructions and medication for treatment of a disease vary depending on the type and severity level of the disease, clinical factors (e.g. age, blood pressure etc.) and physical condition of the user. For example, if a user is in the early stage of Postpartum Blue, it may be controlled by counseling. On the other hand, to control infectious conditions

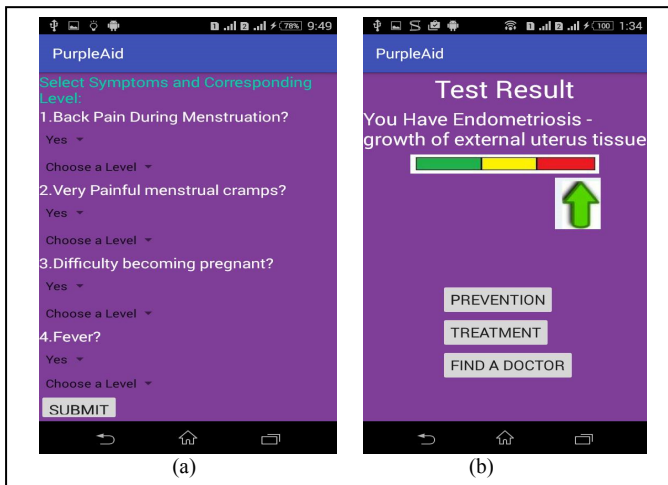


Fig. 2. Implementation of PurpleAid. (a) taking input symptoms from the users , (b) diagnosis of disease with severity level

like UTI etc., treatment includes hygiene maintenance, eating enough water etc. Again, in case of breast cancer or endometriosis, treatment varies from drugs, painkillers, hormone therapy or surgery depending on the stage of the disease and age of the patient [38]. Our system stores treatment measures and medications widely followed by health specialists for different diseases in the app database. For safety measures, we do not show name of any particular medicine, rather suggest to consult doctor, if the condition is severe or likely to be severe.

2) *Find Doctor* : In case of emergency, user may need to consult doctors and specialists for the particular disease immediately. PurpleAid includes features to find out nearby hospitals and specialists if internet connection is available. PurpleAid automatically sets the user's current location using GPS co-ordinates. User can also change their current location to any other location and check for nearby hospitals. We use Google Map Android API to embed the map in our app.

C. Prevent:

This subsystem is designed to provide users with the opportunity to know about the preventive measures associated with a disease beforehand. This feature is specially beneficial for the users with family history of genetically inherited diseases like diabetes, asthma, etc [39]. User may select any disease to know the preventive measures. Suggestions along with pictures and videos are provided for better understanding of the users. We note that preventive measures also vary depending on the gender. For example, thyroid problem is common among women. To prevent this problem, a woman needs to avoid smoking and too much soy, test for and treat thyroid antibodies, take selenium, avoid over-fluoridated toothpastes, drinking water, dental rinses etc [40]. These preventive measures are specially designed keeping in mind that our prime users are women.

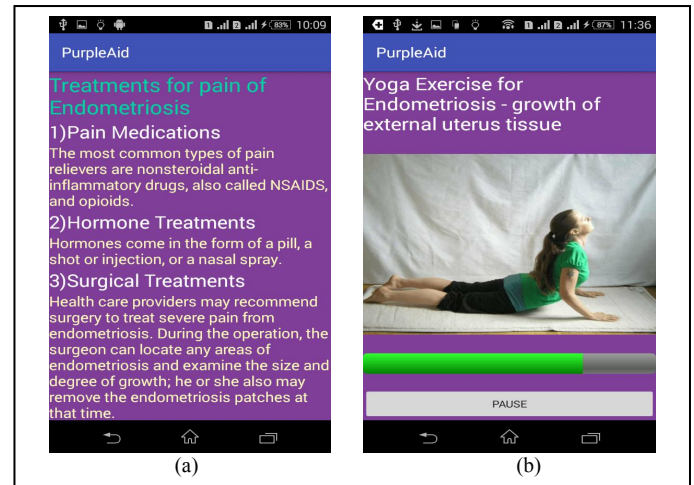


Fig. 3. Implementation of PurpleAid. (a) showing treatments for a disease, (b) showing video of exercises to maintain health and prevent disease

D. Maintain Health:

This subsystem includes features for maintaining regular health and fitness of the users. Within the app, users are able to create their own unique profile ID. This profile ID can be only accessed by the owner through entering a password. Each user can store their health status, (e.g., blood pressure, heart rate, weight, menstrual dates etc.) at a regular interval in their own profile. In this way, swift diagnosis is possible by looking at unusual changes in any of the health status data. This might be extremely useful for patients with chronic problems. For example, the normal menstrual gap for a woman is 28 days. However, this gap is subjective and varies from person to person depending on age, metabolism, hormone level etc. For some woman, a gap of 22 days may be regular, while for some other woman, menstruation may occur in 35 days interval. If menstrual gap changes frequently for a user along with other problems like itching, pain, extensive white discharge, there are possibilities that the user is going through irregular health conditions. As such, personalized diagnosis and treatment of diseases becomes easier when user maintains an individual profile and updates health data regularly.

Additionally, maintaining health feature of our system enables users to control obesity, eating disorder, depression etc. by showing various exercises and health tips. At first, user needs to login to her account and input current health data (e.g., weight, blood pressure, temperature etc.). Our system compares the user's input with her previous health data stored in the database. If any significant discrepancy is found, (e.g., weight loss or increased blood pressure) proper suggestions and instructions are given to the user. Besides, videos of exercises are also shown for better maintenance of health and fitness of the users. Fig. 1 includes the procedure of maintaining health subsystem.

IV. PERFORMANCE EVALUATION

Android 4.0, API- Level 19 is used to build the prototype of the mobile application and Samsung S6 Edge is used to test the prototype. Fig. 3 and Fig. 4 show four screenshots of taking input symptoms from the users, diagnosing probable diseases along with severity level, showing treatment suggestions and video exercises for preventing diseases and maintaining health.

We evaluated our proposed system PurpleAid and measured the accuracy of various features - diagnosis of diseases, the severity level of the diagnosed disease, treatment instructions for diseases, showing nearby hospitals, preventive suggestions and maintaining health. We took 30 trials for each of the four modules and compared the output results with the decisions of doctors of different hospitals from our collected data. Table I shows the results of these trials.

TABLE I. ACCURACY MEASUREMENT OF PURPLEAID

Name of the test	Accuracy Percentage
Detection of disease	83.33%
Severity level of the disease	80%
Instructions for treatment	73.33%
Nearby hospitals	90%
Preventive measures of disease	76.67%
Maintaining health	93.33%

Table I shows that PurpleAid achieves high accuracy for health maintenance and showing nearby hospitals and specialists, significant accuracy for diagnosis of disease and severity level. The slightly increased error rate in the instructions for treatment and prevention of diseases are due to the fact that treatment and preventive measures vary subjectively from doctors to doctors as well as depending on varieties clinical and demographic conditions of the patients.

In addition to the performance evaluation experiments, we conducted a usability test of PurpleAid with four female users. Two of them were suffering from UTI, one from diabetes and one from obesity. We collected users' feedback on the prototype implementation of PurpleAid. The result of the usability test is shown in Table II.

TABLE II. USABILITY TEST RESULTS
G = GOOD, S = SATISFACTORY, P = POOR

Feature	User 1	User 2	User 3	User 4
Test of disease	G	G	G	P
Treatment of disease	S	G	P	G
Nearby hospitals	G	G	G	G
Preventive measures	G	S	S	G
Maintaining health	S	G	P	S

In response to the question whether the instructions and suggestions were helpful and understandable, three commented that the instructions of the app were quite easily understandable

to them, while all suggested that the interface of the app was highly supportive. Moreover, all of the participants acknowledged the need of a mobile application designed for health support of women and showed remarkable interest to use the app, if launched in the market. Thus, the usability test result and performance evaluation pointed out several area for further improvement and also showed that PurpleAid has prospective to be used as a support system for combating health hazards of women.

V. CONCLUSION AND FUTURE WORK

In this paper, we presented PurpleAid, an effective and user-friendly system to detect various health hazards of women and provide suggestions for treatment and preventions accordingly. Our proposed system takes input from users symptoms for diseases that are common only in women as well as both men and women. We use logistic regression model to diagnose probable diseases along with accurate severity level. Moreover, suggestion regarding treatment and early prevention of the diseases are also provided by our system. Besides, we have included feature for regular health checkups and fitness for women. Thus, our proposed system, PurpleAid has the potential to act as a compact mHealth package for handling common health hazards of women, which can lead to mortality and morbidity, if not promptly diagnosed and properly treated. In future, we plan to design a cloud-based system as the app database may not be sufficient to store data associated with large number of diseases. We also plan to make the application more usable for low or semi-literate women of Bangladesh by using our native language Bengali so that our system can provide a wider social impact in the context of Bangladesh.

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