# GDM-PREP: A Rule-Based Technique to Enhance Early Detection of Gestational Diabetes Mellitus

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***Abstract*—Gestational diabetes mellitus (GDM), a condition occurring solely during pregnancy, poses risks to both expectant mothers and their infants, particularly among individuals with pre-existing risk factors. However, early diagnosis and effective management of GDM can help mitigate potential complications. As part of the Ministry of Health's efforts to enhance screening and management strategies for GDM in Malaysia, this study aims utilizing a rule-based technique, acting as an Expert System for Initial Screening of Gestational Diabetes Mellitus Detection. This application will facilitate early diagnosis by assessing risk factors and symptoms to calculate the probability of GDM occurrence and classify it as low, medium, or high. Functionality and usability tests are conducted to ensure error-free performance and gather user feedback. The study's findings indicate that the self-check GDM system effectively utilizes the algorithm, while the mobile application showcases good usability, achieving an above-average System Usability Scale (SUS) score.**

***Keywords—Gestational diabetes mellitus (GDM); rule based; expert systems; risk factor***

## I. Introduction

Gestational diabetes mellitus (GDM), which only manifests during pregnancy, is the term used to describe diabetes during pregnancy. This is a severe condition that causes pregnant women who were previously normal but discovered to have higher levels of blood glucose during pregnancy [1]. GDM is increasing in prevalence, with 21 million cases (or 7% of the global population) being reported globally [2]. The number of pregnant women with GDM is increasing due to changes in eating habits, increased purchasing power, and climate change [3].

In the early stages of pregnancy, the mother's body undergoes several changes that turn her into a different individual with unique physical and mental features leading to changes in health habits and lifestyle. Hence, those habits and lifestyle choices during pregnancy seem to have permanent and long-term effects on the mother's and child's health [4]. GDM raises the risk of short-term and long-term risks in pregnant women, including pre-eclampsia, caesarean section rates, miscarriage, and subsequent lifelong diabetes. Children of mothers with GDM are more probably to have neonatal respiratory distress syndrome and hypoglycemia and develop diabetes, obesity, and metabolic disorders later in life.

Women at risk to develop GDM is when they are having the presence of any risk factors such as a body mass index of more than 27 kg/m2, previous history of GDM, first-degree relative with diabetes, history of macrosomia, bad obstetric history, developed glycosuria ≥2+ on two occasions, and any current obstetric problems. These recommendations from the Clinical Practice Guidelines (CPG) are intended to be clinical practice manuals in Malaysia based on the best information available at the time of development [1].

In support of the Ministry of Health's objectives of continuing to develop improved screening and management strategies for GDM in Malaysia and of preventing the development of type 2 diabetes mellitus in pregnant women [5][6], this study aims utilizing a rule-based technique, acting as an Expert System for Initial Screening of Gestational Diabetes Mellitus Detection based on the risk factors and symptoms.

Early diagnosis of GDM is important to minimize the risk, but in the first trimester of gestation, the Oral Glucose Tolerance Test (OGTT) is ineffective as pregnancy-induced hyperglycemia is not always clearly apparent in the first months of gestation [3]. Therefore, screening for a disease is advised when the disease is common and clinically significant, and when there is a clear screening test that will classify most diseased persons without high rates of false-positive or false-negative outcomes. The early screening of diseases is very important for society as it contributes to improvements in the quality of life and economic growth in the countries. This screening allows the early initiation of proper treatment of the disease to prevent death [3]. In addition, the screening and subsequent detection of GDM before pregnancy enable effective management to reduce maternal and fetal morbidity and mortality associated with pregnancy hyperglycemia [6].

In the research conducted by [7], Malaysia is in the fifth rank in Asia with an 18.5% prevalence rate of GDM. To reduce the prevalence rate in Malaysia and to have good primary care for the mother and patients at risk at a minimal cost, needs a pre-screening test procedure that is easy and gives new knowledge to know better about themselves [8][9]. Several biochemical tests for diabetes diagnosis in early pregnancy were proposed, which as the Oral Glucose Tolerance Test (OGTT). However, it is an expensive and manual test, and its poor tolerability may affect enforcement, especially in the context of nausea during the early stages of pregnancy [6]. Therefore, in this research, the initial screening of the GDM expert system is proposed based on risk factors and symptoms. This initial screening test is the first step in diagnosing GDM in the CPG published by the Ministry of Health Malaysia [1]. However, according to a medical expert, the initial screening test is conducted in a casual interview only, because currently, there is no mechanism for the initial screening of GDM in clinics and hospitals.

Increasing awareness among women and their families about GDM is pivotal to ensure early detection and treatment. "Women who are vulnerable to the risk factors of GDM should contact their doctor before they decide to become pregnant and ensure that they seek guidance and support in the control of their blood sugar,"[20]. Increased risk for the complications of GDM during the first and second trimester of pregnancy is due to poor healthcare [6]. Thus, in order to achieve the best outcome of pregnancy, pre-screening test is an early step that can be taken to avoid the risks [2]. This research is aimed to spread awareness to people that GDM can occur from risk factors. Therefore, initial screening is advised as it can be a precautionary measure before and during the pregnancy to prevent complications.

The main contribution is the development of GDM-PREP, an innovative mobile application that employs rule-based techniques to improve the early detection of Gestational Diabetes Mellitus (GDM). By seamlessly integrating with the mobile environment, GDM-PREP offers a user-friendly and accessible platform for expectant mothers. The application incorporates a set of carefully designed rules and symptoms tailored to the Malaysian context, ensuring accurate classification and timely detection of GDM in this specific population.

## II. Related Work

This section discusses existing mobile applications for pre-screening GDM There are a few expert systems that had been developed, which are d-GDM 2019, Gestational Diabetes Health Tips & Care, Diabetes Diagnostics and Diabetes Test - risk calculator of Diabetes.

d-GDM is an interactive mobile application that was created in 2015 by Garnweidner and Cols [10]. Garnweidner and Cols.'s aim for the application is to diagnose and give information regarding the result to be followed up to present on a mobile phone screen. The application was developed using WHO's suggested variables and parameters of GDM which are fasting glycemia, random glycemia, and glycated haemoglobin (HbA1c) in the first trimester. d-GDM applied an open source for all the informatics tolls of the application. The application will generate and present the information regarding the result of the diagnosis of GDM after the user submitted all the information needed in the application.

Diabetes Diagnostics has been developed by Natural Apptitude with a team of world leaders, which is the University of Exeter Medical School team who lead the diabetic monogenic diseases and the front line of work in diagnostic aids for subtypes of diabetes. It can be retrieved from the website (https://www.natural-apptitude.co.uk/project/diabetes-diagnostics/). It is an application that helps physicians worldwide detect unusual types of diabetes, as objectively to provide patients with improved care. Natural Aptitude also stated that this probability calculator is created in a mobile application for offline use, along with a range of other diagnostic tools and other information aimed to increase the accuracy of the diagnosis. The application needs several important informations about the user, such as age, sex, racial group, BMI, HbA1c level, and other risk factors. The best feature of Diabetes Diagnostics is that it displays a probability of the diagnosis, as it gives a description of the disease in the result section.

Diabetes test - risk calculator of diabetes is a mobile application which requires iOS 8.0 or later that was created in 2017 by Pears Health Cyber can be accessed through (https://apps.apple.com/us/app/diabetes-test-risk-calculator-of-diabetes/id1014960572). The developer of the application claimed that the Diabetes Test - risk calculator of diabetes is a multiplex and reliable risk calculator on a mobile device for the development of diabetes mellitus. They also added that "We have developed a test using a combination of many test algorithms that takes account of a wide range of variables that can detect smaller degree than any other risk calculator." The result then will be generated after simply enter in the application of the details of age, gender, family anamnesis, physical health, BMI, and other factors.

## III. Methodology

### A. Expert System

An expert system is one of artificial intelligence (AI) technologies. Expert systems (ES) are systems based on knowledge which are part of the former AI research field and can be defined as knowledge-intensive software that performs tasks that usually require human expertise [11].

- Rule-Based

A rule-based system is a system that uses laws as the main principle of representation [12]. The meanings of a rule-based system depend almost entirely on ES which imitates human expert reasoning in solving an intensive problem of knowledge [13]. It also stated that a rule-based system encodes a human knowledge expert into an automated system in a rather narrow area. The rules consist mainly of two parts rule antecedent and rule consequent, where the rule antecedent is the if the part that specifies a set of predictor attribute values referencing the conditions. While the rule consequent is then part which specifies each example that the predicted class of the rule meets the conditions in the rule antecedent [14]. A rule-based system usually consists of a variety of if-then rules that can be used for various purposes, such as reinforcement of decisions or predictive decision-making [15]. The rule base is the set of rules which represents the knowledge about the domain [12]. The general form of a rule is such below:

*If cond1 and cond2 and cond3 ...*

*then action1, action2, ...*

The conditions cond1, cond2, cond3, etc., also known as antecedents are evaluated based on what is currently known about the problem being solved. Some systems would allow disjunctions in the antecedents. For example, the rules in general form. Such rules are interpreted to mean that if the antecedents of the rule together evaluate to true for example if the Boolean combination of the conditions is true, the actions in the consequents which are the action1, action2, etc., can be executed. Each antecedent of a rule typically checks if the problem instance satisfies some condition. For example, an antecedent in a rule in a medical expert system could be the patient has previously undergone heart surgery. The complexity of antecedents can vary a lot depending on the type of language used. For instance, in some languages, one could have antecedents such as the person's age being between 10 and 30.

The advantage of the rule-based system is the structures, as its homogeneity therefore the uniform syntax enables one to easily analyze the context and interpret each rule [16]. There is also a limitation to the rule-based system which is, the rule-based system will provide an inadequate explanation. Most expert systems offer a facility to explain the user's behaviour. There are very few explanatory facilities provided by a rule-based system. Therefore, the explaining facilities provided by a rule-based system are only suitable when the user and the expert are equally knowledgeable.

Research by [3] applies Bayesian Network, Multicriteria Analysis and Expert Systems to improve GDM diagnosis from data mining techniques, which will display more reliable random trees and a lower error rate result from the experiments. Registration of rules to facilitate diagnosis and the accuracy of the tests can be enhanced by increased rules, thereby increasing the specialty of the system and its ability to function in its domain. Another study [17] proposed a rule-based diagnosis system for diabetes. Technique Fuzzy-based logic rule is ideal to develop a system of knowledge based on medical disease. The proposed expert system is very useful both for the patient and for doctors to diagnose the disease correctly. The laboratory test results can differ in certain ways, and it is time-consuming since they depend entirely on the availability and expertise of the physicians. Besides, a model proposed by [9], can help to diagnose T2DM early and avoid potential complications linked to late diagnosis. Although the absence of laboratory diagnostic tests on diabetes decreased the sensitivity and accuracy of the proposed model in the research, the model is an evolution of an early diagnosis of diabetes without using laboratory diagnostic tests.

## B. Pre-Screening of GDM

Gestational Diabetes Mellitus (GDM) is related to an increased risk of short and long-term maternal and perinatal complications [18]. Early screening, diagnosis and diabetes prevention reduce the high costs of disease control and complication treatments and prevent admission into the hospital due to serious complications [9]. There are various guidelines for screening and diagnosis of GDM such as guidelines from the World Health Organization (WHO), National Institute for Health and Clinical Excellence (NICE), American Diabetes Association (ADA), etc. However, this research will follow the CPG published by the Ministry of Health of Malaysia as a reference. This section will be explained on Algorithm of GDM in CPG and the risk factors and symptoms of GDM.

- Algorithm of GDM in CPG

Based on Fig. 1, the first step of screening and diagnosis of GDM is screening the patient at risk to develop GDM and women age more and equal to 25 with no other risk factors. It will then proceed with 75g OGTT to confirm that the patient is diagnosed with GDM. Therefore, the screening test is important as it is a determinant of the OGTT to be conducted. In addition, the identification of risk factors is significant to determine whether women are at risk for an early diagnosis and intensive lifestyle changes [7].

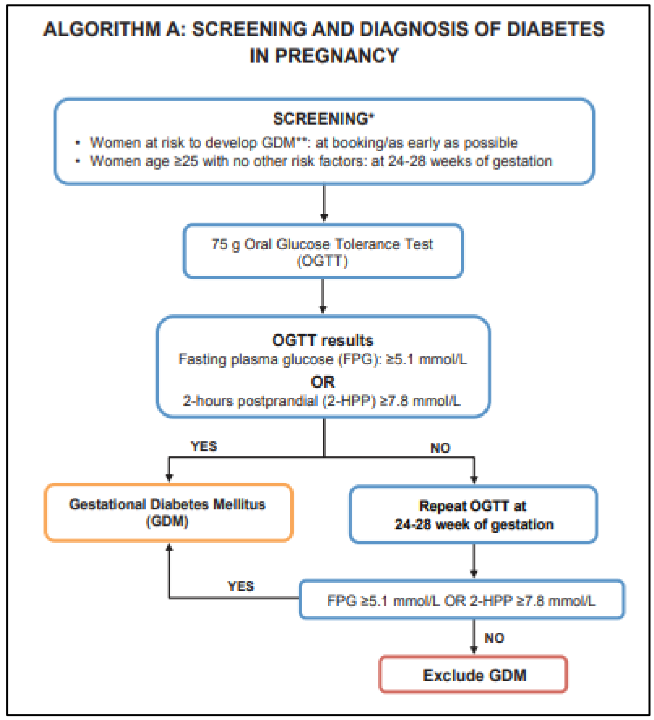



Fig. 1. Algorithm of screening and diagnosis of GDM stated in CPG.

## C. Risk Factors and Symptoms of GDM

Although many other risk factors are also considered in another guideline for screening and diagnosis of GDM, Malaysian CPG will only use seven risk factors to diagnose GDM. As shown in Fig. 2 the risk factors of GDM are Body Mass Index (BMI) of more than $27kg/m^2$ and experienced GDM in a previous pregnancy. In addition, first-degree relative with diabetes is also a risk factor for GDM. The first-degree relative's would-be parents, siblings, and children [19]. Other than that, history of macrosomia, in which the birth weight of the baby is more than 4 kg. The next risk factor is the patient who experienced bad obstetric history and glycosuria, where the urine contains more blood sugar than usual on two occasions. The one who is facing obstetric problems, such as essential hypertension, pregnancy-induced hypertension, polyhydramnios, or current use of corticosteroids, would be the last risk factor for screening and diagnosis of GDM.

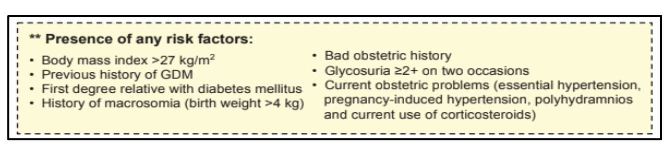



Fig. 2. Risk factors of GDM are stated in CPG.

Next, there are five symptoms of GDM [18]. The symptoms are polydipsia, which is excessive thirst and polyuria. Polyuria is a condition where the body urinates more than normal and each time you urinate, it passes excessively large amounts of urine. Other than that, the patient might suffer exhaustion, nausea, and repeated vomiting. Lastly, the symptom of GDM is blurred vision, which experienced a decrease in clarity or sharpness vision.

The objective of this research is to classify the user with GDM. Risk factors and symptoms of GDM will be used as an indicator in this research. Based on various previous research, rule-based is an ideal technique to develop an expert system for a diagnosis of a disease. Rule-based has also been applied as its structures provide procedural interpretations that allow them to be viewed as models of computation. Although BN has an adaptability feature, a rule-based system dividing the rule base from the inference engine distinguishes the knowledge from the way of how to solve the problem. This means that the same inference engine can be used with several rule bases and a rule base for different inference engines may be used. Therefore, it is easy to add or apply a new rule with the same bases or antecedent.

## D. Risk Factors and Symptoms Selection

This research is focused on the self-check function. In the function, there are two parts, which are risk factors and symptoms of GDM that have been used as the parameters for the self-check function. All the information about the parameters had been collected and gathered from the Clinical Practice Guidelines: Management of Diabetes in Pregnancy, published by the Ministry of Health Malaysia. There is also additional information that had been gathered on the parameters of the self-check function, where each of the parameters has its impact on the result generated.

In addition, the data and information on parameters are collected and have been revised and verified by the medical expertise. Therefore, there are seven risk factors and five symptoms of GDM. The risk factors of GDM, there is a body mass index of more than 27 kg/m2, previous history of GDM, first-degree relative with diabetes, history of macrosomia, bad obstetric history, developed glycosuria on two occasions, and any current obstetric problems. Meanwhile, the symptoms of GDM, there are polydipsia, polyuria, exhaustion, nausea, repeated vomiting, and blurred vision.

## E. Algorithm

The rule of GDM detection is designed in algorithm form before the development of the system and implemented in Java. Two conditions are to be applied by rules. The first condition is the user will only be answering for the risk factors section in the self-check function. The second condition is the user will be answering both the risk factors and symptoms section. The condition that will be experienced by the user in the self-check GDM function is based on the result generated from answering the risk factors section. There are seven questions regarding risk factors. Each question referred to each risk factor. For each question, if the user answered ‘Yes’, the number recorded in the parameter ‘total parameter’ is incremented from 0 to be used to calculate the probability. As for the user that experienced answering symptoms question, five questions need to be answered. Each question referred to each symptom. The total number of ‘Yes’ answered by the user is recorded in the same parameter, the ‘total parameter’ which is incremented from the question in risk factor. Fig. 3 shows the algorithm of the rule of GDM detection in pseudocode.

```
IF (Total Risk Factor = 0%)
    THEN GDM = Low
IF (Total Risk Factor < 20% AND Risk 2 = No)
    THEN GDM = Low
IF (Total Risk Factor < 50%)
    THEN GDM = Medium
IF (Total Risk Factor < 50% AND Risk 2 = Yes)
    THEN GDM = Medium
IF (Total Risk Factor < 50% AND Risk 1 = Yes)
    THEN GDM = High
IF (Total Risk Factor > 50%)
    THEN GDM = High
IF (Total Risk Factor and Symptoms < 50%)
    THEN GDM = Medium
IF (Total Risk Factor and Symptoms > 50%)
    THEN GDM = High
IF (Total Risk Factor and Symptoms < 50% AND Risk 1 = Yes)
    THEN GDM = High
```

Fig. 3. Rules Generation for GDM detection.

After users have answered all questions, the probability of having GDM will be calculated based on their input in each question of risk factor or both risk factor and symptom. The value of the ‘total parameter’ will be collected from the user on what they are experiencing in their current condition, and it will be then divided into the total number of risk factors or divided into both the total number of risk factors and symptoms. Then, it will multiply by 100 to get the probability. To be simplified, the formulas to calculate the probability are shown in Table I.

TABLE I. THE FORMULA OF THE PROBABILITY OF HAVING GDM

| Condition | Formula to calculate the probability |
|---|---|
| The user answered risk factors only. | $\frac{Total\ Yes}{7\ (Total\ Risk\ Factor)}\ x\ 100$ |
| The user answered risk factors and symptoms. | $\frac{Total\ Yes}{13\ (Total\ Risk\ Factor\ and\ Symptom)}\ x\ 100$ |

From the Algorithm 1, the user will get the result of their probability of GDM based on 7 or 13 parameters depending on the result in the risk factors section. The result in the risk factors section must be more than 50% and the user is currently pregnant to answer the symptoms section. Otherwise, the user will only need to answer the risk factors section to get their probability to have GDM. There are three categories to classify the probability of GDM, which are low, medium, and high. The example of cases for classifying the probability from rules is visualized in Table II.

**Algorithm 1:** Algorithm for the rule of GDM detection.

```
Initialize
Tp = 0; P = 0;
Compute
While () do
    For (each Risk Factor 1 to Risk Factor 7) do
            IF Ri is YES, then
                Ri = 1 AND Tp = Tp+1, Otherwise 0;
            End

    IF (P > 50 AND Pregnant =YES)
        THEN FOR each Symptom 1 to Symptom 5 DO
            IF Si is 'YES'
                THEN Si = 1 AND Tp=Tp+1, Otherwise 0;
            End
            P = (Tp/13) x 100
    Else
        P = (Tp/7) x 100
        End

    Return Tp and P;

    End
End
```

Next, based on Fig. 3, the rule to classify the use of probability to have GDM is based on the user risk factors or both risk factors and symptoms. User needs to answer each risk factor and symptom-based on their current condition. Based on the answer by the user, it will then be calculated the probability to have GDM. Then, the rules will be implemented in the classification of the probability. If all the parameters match the rule, then the probability and classification for the user will be produced because of the self-check function.

## F. *User Interface (UI) Design*

On the Home page, there is one function for the user to have their probability to have GDM by clicking the Self-check GDM option. Users need to answer each question displayed as shown in Fig. 4. To submit the answer based on the user's current condition, they need to click one option from the radio group and click the button NEXT and click on the button SUBMIT on the last question.

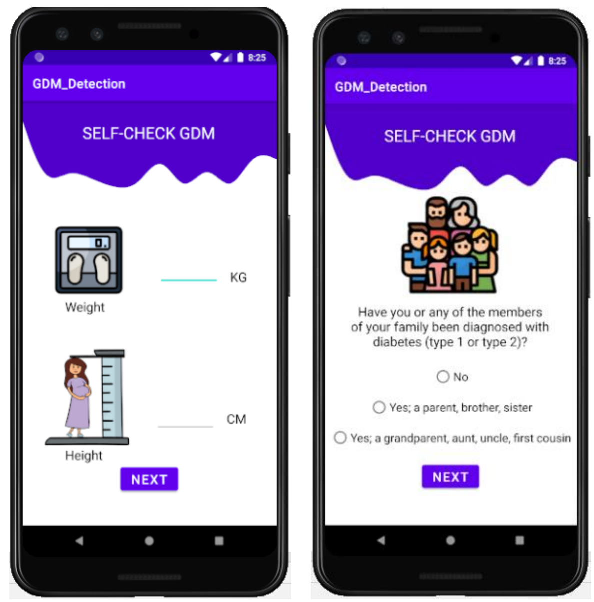



Fig. 4. Sample of self-check GDM questions page.

TABLE II. EXAMPLE OF CASES FOR CLASSIFYING THE PROBABILITY FROM RULES

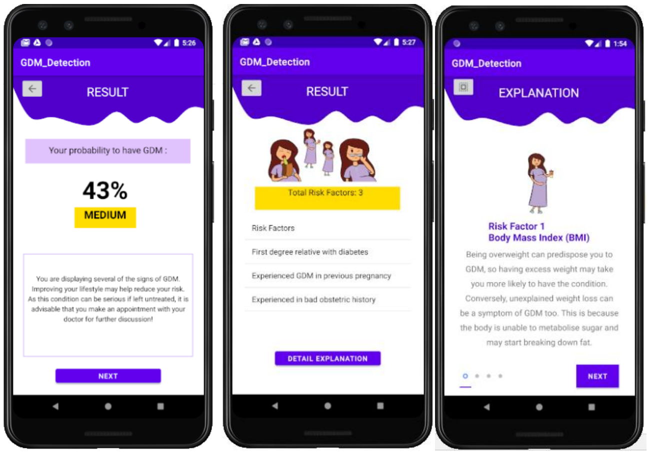
| No | R1 | R2 | R3 | R4 | R5 | R6 | R7 | S1 | S2 | S3 | S4 | S5 | Probability | Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | No | No | No | No | No | No | No | No | No | No | No | No | 0% | LOW |
| 2 | No | No | Yes | No | No | No | No | No | No | No | No | No | 14% | LOW |
| 3 | No | No | Yes | No | No | Yes | No | No | No | No | No | No | 29% | MEDIUM |
| 4 | No | Yes | Yes | Yes | No | No | No | No | No | No | No | No | 43% | MEDIUM |
| 5 | Yes | Yes | No | No | No | No | No | No | No | No | No | No | 29% | HIGH |
| 6 | Yes | No | No | No | No | No | No | No | No | No | No | No | 14% | HIGH |
| 7 | No | Yes | Yes | Yes | Yes | No | No | Yes | No | Yes | No | No | 46% | MEDIUM |
| 8 | No | No | Yes | No | Yes | Yes | Yes | No | Yes | No | Yes | Yes | 54% | HIGH |
| 9 | Yes | Yes | No | No | No | Yes | No | Yes | No | No | No | No | 31% | HIGH |

**Indication:**

| | | | |
|---|---|---|---|
| R1 | BMI of more than 27 kg/m2 | S1 | Polydipsia |
| R2 | First-degree relative with diabetes | S2 | Polyuria |
| R3 | Previous history of GDM | S3 | Exhaustion |
| R4 | History of macrosomia | S4 | Nausea, repeated vomiting |
| R5 | History of bad obstetric | S5 | Blurred vision |
| R6 | Glycosuria | | |
| R7 | Current obstetric problems | NoP | Do not experience R7 but pregnant |

After the user submits all their answers to all the questions, the application will display the result page. On the result page, there is the Home button for the user to view the Home page and the Next button for the user to review the detailed explanation of the result displayed. Fig. 5(a) shows the Result page. In Fig. 5(b), the total risk factor that strikes the risk factor of GDM will be displayed, based on the user's answer. If the user wants to return to the previous page, click on the Back icon. On the Detail Explanation page, it will view all explanations on the user's answer on each parameter. It contains the Home icon and Next icon. If the user wants to return to the home page, click on the Home icon. Click the

Next icon if the user wants to view the next explanation for the next parameter and click the bullet icon if the user wants to view the previous explanation for the previous parameter, as shown in Fig. 5(c).




(a) (b) (c)

Fig. 5. Sample of result page where (a) represents percentage page, (b) represents risk factor and, (c) explanation page.

## IV. Result and Discussion

In this section, the implementation of the rule for the first condition of the algorithm will be discussed first. There are seven parameters to be considered in the first condition. It consists of the risk factors of GDM. There is a body mass index of more than 27 kg/m2, previous history of GDM, first-degree relative with diabetes, history of macrosomia, bad obstetric history, developed glycosuria on two occasions, and any current obstetric problems. From all the answers submitted by the users with the most suitable current condition for the seven parameters mentioned above, the result of the probability of the users having GDM will be obtained. There are three classes of the probability of GDM, which are low, medium, and high. The rule to classify the probability of GDM is shown in Fig. 6.

Table III concludes the classification of the result based on the probability calculated and extra conditions considered for the result. To be classified in the low class of the probability of GDM, the result of the probability must be 0% or less than 20% and the second risk factor of GDM, which is the user's parent, brother or sister is experienced diabetes is false. However, to be classified in the medium class of the probability of GDM, the result of the probability must be more than 0% and less than 50%. Other than that, if the probability is more than 0% and less than 50%, and the second risk factor which is the user's parent, brother or sister are experienced diabetes is true, the user also will be classified in the medium class of chances to have GDM. Next, to be in the high class of the probability of GDM, the result of the probability must exceed 50%. In addition, if the user's BMI is more than 27 kg/m2, the user also will be classified in the high class of the probability of GDM.

```
if((result_to_refer > 50 && referSymp.equalsIgnoreCase( anotherString: "no")) ||
        (result_to_refer < 50 && vR1 > 27) ||
        (result_to_refer > 50 && referSymp.equalsIgnoreCase( anotherString: "yes"))){
    result_exp.setText(exp_high);
    classs.setText("HIGH");
    classs.setBackgroundColor(Color.parseColor( colorString: "#D61A1A"));
}
else if(result_to_refer == 0 ||
        (result_to_refer < 20 && (!viewRisk2.equalsIgnoreCase( anotherString: "Yes; a parent, brother, sister")))){
    result_exp.setText(exp_low);
    classs.setText("LOW");
    classs.setBackgroundColor(Color.parseColor( colorString: "#93DE50"));
}
else{
    result_exp.setText(exp_med);
    classs.setText("MEDIUM");
    classs.setBackgroundColor(Color.parseColor( colorString: "#FFDD00"));
}
```

Fig. 6. The rule to classify the probability.

TABLE III. Classification of Result based on the Probability Calculated and Extra Condition

| Class | Probability | Extra condition |
|---|---|---|
| Low | 0%<br>Less than 20% | <br>Risk 2 is false |
| Medium | More than 0% and less than 50%<br>More than 0% and less than 50% | <br>Risk 2 is true |
| High | More than 50%<br>Any probability | <br>Risk 1 is true |

For the second condition of the algorithm, it will only be implemented if the result in the first condition, which is the result of the probability exceeds 50% and the users are currently pregnant. In this condition, the user will answer questions about the symptoms of GDM. There are 13 parameters to be considered. There are seven risk factors in the first condition and another five symptoms of GDM, which are polydipsia, polyuria, exhaustion, nausea, repeated vomiting, and blurred vision. The classification of the probability of the prevalence of GDM for the second condition is medium and high only. It is based on the probability calculated in which the 13 parameters are all considered. The user will have a medium class of probability if the result of the probability is more than 0% and less than 50%. The user also will have a medium class of probability of GDM if the probability is between 1% to 50% and the second risk factor which is the user's parent, brother or sister is experienced diabetes is true. And the high class of probability is if the result of the probability is exceeded 50% and the user's BMI is more than 27 kg/m2.

### A. *Usability Testing*

Usability testing is the process of testing with a community of representative users on how simple a design of the system is to be used to ensure that the program is results-oriented, easy to use, reliable and easy to implement into the everyday life of the user. There are several usability assessments, and which survey is one of the usability tests to be used in this project. Target users who are consisted of pregnant women, married women, and the team of the Clinical Practice Guideline of the Ministry of Health Malaysia. The survey has been conducted via video conferencing with 10 respondents. The average total System Usability Scale score is 86.75.

The respondents need to answer on a scale from scale 1 to scale 5 in usability testing questions. Scale 1 refers to strongly disagree, scale 2 refers to disagree, scale 3 refers to neutral, scale 4 refers to agree, and scale 5 refers to strongly agree. From all the results of each question given in the SUS questionnaire to 10 respondents among the target user, Table IV shows the total score for each respondent that has been calculated based on the result of the SUS questionnaire. Questions 1, 3, 5, 7 and 9 are odd. Therefore, it needs to subtract by 1. For the even statements, questions 2, 4, 6, 8, and 10, will be subtracted from 5. Then, to get the result, all the scores that have been subtracted will sum up and multiply by 2.5. Based on Table IV and Fig. 7, the average SUS score obtained for the application is 86.75. From the result, it can be concluded that the application has good in terms of usability by achieving the average SUS score, which is more than 68 scores.

TABLE IV. TOTAL SCORE FOR 10 RESPONDENTS BASED ON SYSTEM USABILITY SCALE

| **Respondents** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **A total score of the application** | 82.5 | 100 | 85 | 90 | 62.5 | 100 | 80 | 85 | 87.5 | 95 |

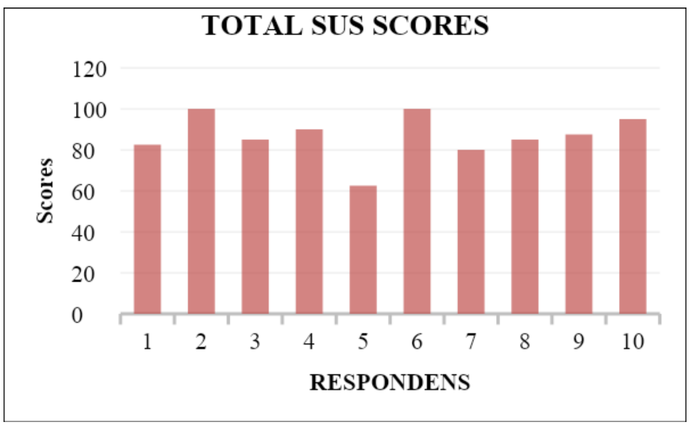



Fig. 7. Bar graph of total SUS scores.

# V. CONCLUSION

## A. Strengths and Limitations

The development of the system is basically to ease the user to have their current probability based on the risk factors and symptoms. With the detailed explanation provided, it also eases for the user to refer to the information, for future use without the need to refer to the hard copy of the clinical practice guideline. Due to the time constraint in collecting the information with the expertise, the application is only focused on one type of diabetes, which is GDM, known as diabetes in pregnancy. Thus, make this application data scope only GDM. As for that, the application does have only one main function, which is the function of the user to have their probability to have GDM. Furthermore, the application only supports the English language.

## B. Conclusion and Future Research

To enhance the application's capabilities, future research is suggested to explore the implementation of various machine learning techniques. By comparing user data with existing cases of GDM that share similar risk factors and symptoms, the application's diagnostic accuracy and precision can be further improved.

While the GDM-PREP currently focuses on improving health outcomes related to Gestational Diabetes Mellitus, there is potential for expansion to handle extensive databases and diagnose a broader range of diseases. This adaptability allows the system to address multiple health conditions, increasing its overall impact and usefulness in healthcare settings.

This novel approach holds the potential to significantly enhance GDM screening and management strategies in Malaysia, thereby benefiting both healthcare professionals and pregnant individuals.

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