Design and development of application for managing diabetes

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Abstract—Diabetes, the chronic non-communicable diseases which take long time medication, is still be a problem of public health in every country. Plus, diabetic patients prefer non-medicine process which requires many recordings of data and cause patients' life more difficult.

In this study, we developed software for tracking diabetes patients. This project is divided into 2 parts, i.e., mobile application for diabetic patients and web application for medical staff which data is linked by database. Mobile application was improved from user daily recording log-book combined with psychosocial. It will help patient recording and analyzing data for self-managed care program. Image Classification is the computer vision technique used for automatically fill-in menu name of the food. React native expo was used for developing 1 code base for cross-platform mobile application; android and iOS. In web application, there are 2 tabs; food scoring tab and patient display tab. Nutritionists can review and edit food score on food scoring tab.

Test case, SUS, image classification test accuracy and SUPR-Q are evaluated for the performance of the application. Mobile application has 83.25 SUS score (n=10) and 81.12% for food image classification. Web application has 86.625 SUPR-Q score (n=10).

Keywords—diabetes, mobile application, react-native, web application, psychosocial, classification

I. INTRODUCTION

An ascent of world grown-up diabetes from 463 million to 700 million in the following 25 years demonstrates the emergence of health issues worldwide. [1] The number of people with diabetes is increasing, especially in low-and middle-income countries. [2] The rise of type 2 diabetes states that people didn't take care of themselves because diabetes necessary need life-long medication. It seems to be severe because diabetes is coming with other illnesses such as stroke, heart failure, kidney disease, amputation, and blindness. [3][4] Moreover, our world is facing with 760 billion USD in health consumption in 2019, which estimate to employ 845 billion USD by 2045.[5] Similarly, Thailand has about 4.3 million diabetes that over the estimated number of diabetes that forecast to have in 2035. [1] Not only the rising of diabetes and economic problems, but more than 50% of people also don't know that they are diabetes or not. [5]

Many factors are related to glycemic control and hard to take control such as foods, activities, emotions, stress, depression, attitude, behaviors, medicines, etc. [6][7][8] Most patients prefer a non-medicine program even though it has many cure methodologies, improving diabetes prevention programs without medicine requires many recordings of data

and make patients' life more difficult. Some patients cannot follow a program because of their daily life activities, environments, financial problems, etc. Few patients don't understand about a medication.

In contrast, the small community in Sung Noen, Nakhon Ratchasima, Thailand can control glycemic control with the non-medicine process. Psychosocial and health literacy are two main theories that help them succeed in a program. They manage their own care program with help from public health staffs. Moreover, people in the group always communicate and exchange information. They also compare their control result with others, compete, and ranking for motivating and encouraging. This process may help this group decreases their blood glucose level without medicine. The protocol of this group seems like the peer support - one example of diabetes self-management education and support (DSMES) [9]

DSMES has been associated with improving diabetic self-care behaviors and knowledge [10], improving QOL, and lowering A1C by as much as 1% in people with type 2 diabetes [11] and lowering the mortality rate. Plus, cardiovascular risk factors, and diabetes management can positively improve under the health care community like lay leaders, peer supporters, and community health workers. [10]

II. METHODOLOGY

A. Research Flowchart

This research aims to develop the system for managing diabetes for Thai users. Before application development, literature review, expert consulting, and user interview were focusing to understand user limitations. Log-book and mock-app are designed to validate that the system is fine-tuning between users and medical staff's requirements. The application development has 3 main parts; mobile application, web application and database. The system was evaluated. The research flowchart can be seen in Fig. 1.
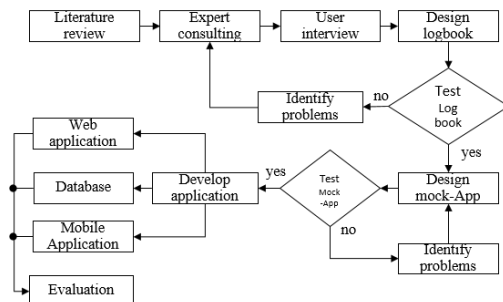

Fig. 1. Research flowchart

B. System Concept

The system has 3 main parts and 2 user groups, they are user and medical staff. Mobile Application is used for collecting user information, dietary, exercise, sleep, information, and blood glucose level, then stored in the database by internet connection. The stored data can be analyzed and giving feedback to user displaying both raw and analyzed data on mobile app. The back-end system is database and storage storing user information and image. User's information is monitoring by medical staff via web application showing analyzed data of every user giving mean and ranking in each information. Web application has a food scoring feature, helping nutritionists to add and edit the food's score enhances food scoring feature to be more accurate. Web is connecting to the database by the internet by rest API. The system concept is shown in Fig. 2.
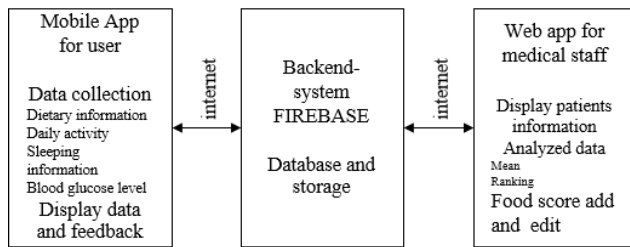

Fig. 2. System concept

C. Use Case Diagram

The use case diagram shown in Fig. 3. is used to specify which field that users can access and which field that medical staff can access. The mobile application allows users to add and access the user's data also edit some profile fields, weight, height, career, town, and province. Users are not allowed to view the other user information directly. In the ranking menu, only other user's score is used in quintile calculation, the name field is not accessed. Medical staff can monitor every patient score and blood glucose level in any data via web application and uses food scoring feature by adding, editing, or deleting food score that use for user's food scoring.
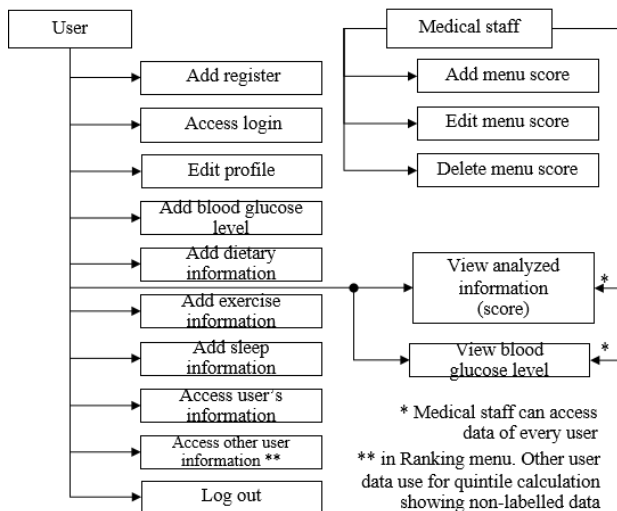

Fig. 3. Use case diagram

D. Activity Diagram

The function in both mobile application and web are described in flow chart.

Using Application users need to fill in a registration form and consent form on register screen. The fields have 3 types of fields. Name, surname, town, province, and career are strings. Age (in year unit), weight (in kg. unit), and height (in cm. unit) are numbers. Consent form showing in text for user to read and allow the system to collect data is Boolean defaulting is false and true when user fills in consent form. All data pre-process differently, string by checking is it null, number by checking is it an integer, and consent needs to be true for register. If the consent form is false the system will alert refusing to register. When all text fields are not null, number fields are integer and consent is true, the system creates a user containing 9 fields and adds time stamp of consent into collection then the registered success. The register flow is shown below in Fig. 4.
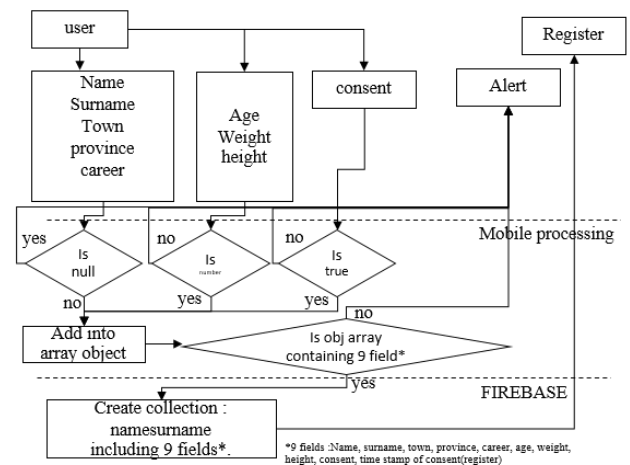

Fig. 4. Activity diagram for register

Log-in feature requires 4 fields, name, surname, town, and province, all data is checking not being null and sent name and surname to fetch data in the database find town and province. One case that login success is the name and surname exist and town and province are matched in database. Diagram is shown in Fig. 5.
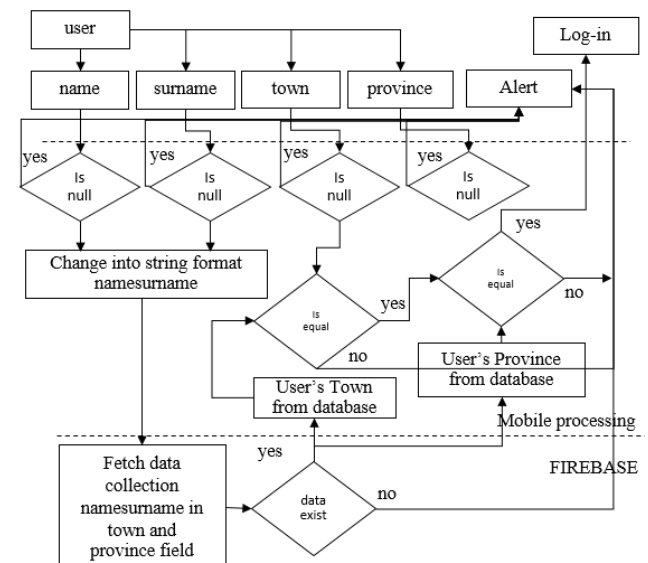

Fig. 5. Activity diagram for Login

Collecting data in Today screen, there are 4 activity diagrams for each data collection. In dietary information, user provides at least 2 fields; image and quantity of food in case that food is in the top 20 menus that image classification is trained to classify, menu is auto fill in menu field if not the user needs to fill in menu field himself shown in Fig. 6. In exercise information, the only field need is time of sweat exercise. Exercise activity diagram is shown in Fig. 7. In sleeping information need 2 fields, sleeping hours and sleep quality shown in Fig. 8a. These 3 data collections have pre-processing and back-end processing to score input data, storing them in database linking to ranking. In blood glucose level (BGL) has pre-processing check the input then store data in database. The diagram is shown below, Fig. 8b.
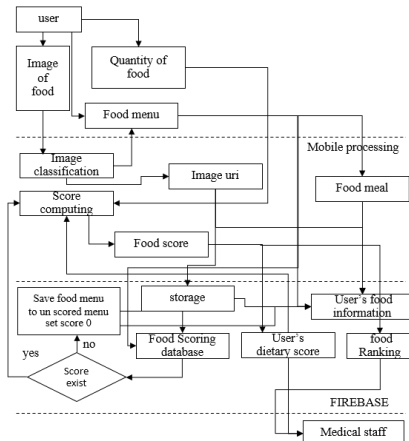
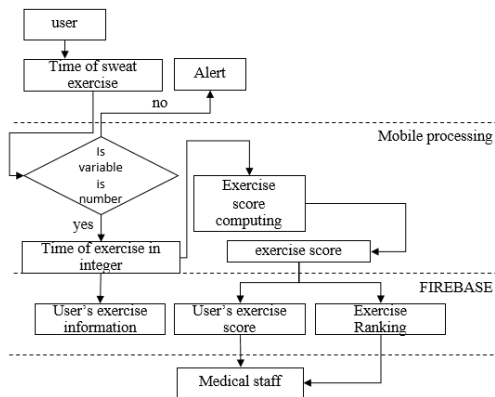Fig. 6. Activity diagram for collect dietary information

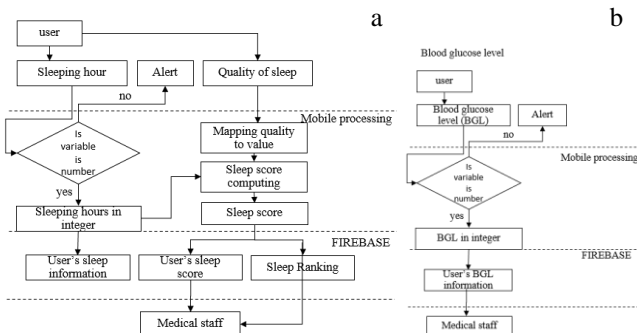Fig. 7. Activity diagram for collect exercise information

Fig. 8. a) Activity diagram for collect sleep information
b) Activity diagram for collect BGL information

Data display on Mobile application has 3 screens. History shows raw data input from users from selected data (Fig. 9a). Overview shows week score of food, exercise, and sleep in range 0-10 labeled with feedback colour, red for the need of improvement (score range 0-3), yellow for fair (score range 4-7), and green for good (score range for 8-10) and giving encouraging by mean in a week. If there is no data on that week the system reminds user to fill in the data. The activity of overview diagram is shown in Fig. 9b. Ranking screen ranking from the dietary score, exercise times, and sleep score evaluated day by day. Quintile is used for ranking and its result show in star range 1-5. If there is no data the star shows all grey. The history ranking view is available in this screen by changing date input (Fig. 10.). All display view models are managing by MVVM preventing call of un-exist data and managing dynamic data fields.
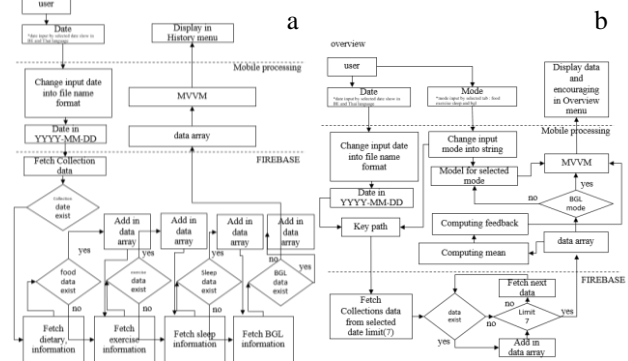
Fig. 9. a) Activity diagram for history screen
b) Activity diagram for overview screen
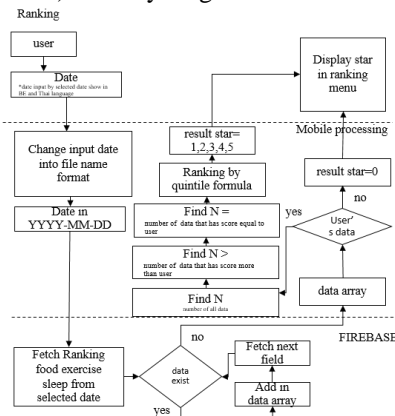
Fig. 10. Activity diagram for ranking screen

The web application has 2 screens for cuisine scoring features and patients monitoring. In food scoring feature activity is followed by Fig. 11. In user monitoring show 3 analyzed data, dietary, exercise, and sleep, and blood glucose level (mg/dl) of every user. The display data provides name and score or BGL and mean of score and BGL. This activity diagram is shown in Fig. 12.

Fig. 11. Activity diagram for cuisine score

Fig. 12. Activity diagram for monitoring

E. Image Clasiification

Image Classification is the function for collecting dietary information which help users to automatically fill-in menu name of food if the food is in the list.
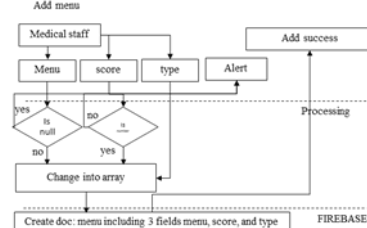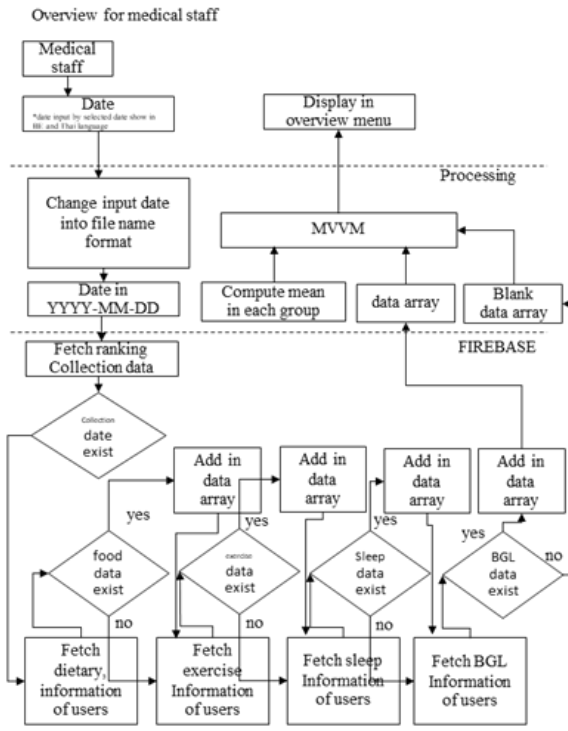
Before training the model, the first step was pre-processing. Next was image augmentation, followed by training model which pre-trained model features and architecture are shown in Fig. 14 and Fig.15. The specifications of optimized training are shown in Fig.16 and the train-validation-test split ratio is shown in Fig 17. After got proper trained model, then used tensorflow.js to transfer model and weights to json and bin files and implemented with the react native expo by using Tensorflow.js React Native and WebGL backend as shown summary in Fig. 13. Deleting resize layer if using tf.applications was needed because resize layer is not compatibility with react native.
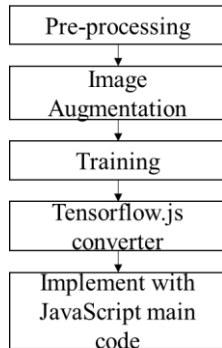

Fig. 13. Summary of image classification processes.

Model	MobilenetV3 (small 1.0)
Model parameters	2.5 M
Top 1 accuracy	67.36%
Top 5 accuracy	87.45%

Fig. 14. Pre-trained model features.

Input	Operator	exp size	#out	SE	NL	s
$224^2 \times 3$	conv2d, 3×3	-	16	-	HS	2
$112^2 \times 16$	bneck, 3×3	16	16	✓	RE	2
$56^2 \times 16$	bneck, 3×3	72	24	-	RE	2
$28^2 \times 24$	bneck, 3×3	88	24	-	RE	1
$28^2 \times 24$	bneck, 5×5	96	40	✓	HS	2
$14^2 \times 40$	bneck, 5×5	240	40	✓	HS	1
$14^2 \times 40$	bneck, 5×5	240	40	✓	HS	1
$14^2 \times 40$	bneck, 5×5	120	48	✓	HS	1
$14^2 \times 48$	bneck, 5×5	144	48	✓	HS	1
$14^2 \times 48$	bneck, 5×5	288	96	✓	HS	2
$7^2 \times 96$	bneck, 5×5	576	96	✓	HS	1
$7^2 \times 96$	bneck, 5×5	576	96	✓	HS	1
$7^2 \times 96$	conv2d, 1×1	-	576	✓	HS	1
$7^2 \times 576$	pool 7× 7	-	-	-	-	1
$1^2 \times 576$	conv2d, 1×1,NBN	-	1024	-	HS	1
$1^2 \times 1024$	conv2d, 1×1,NBN	-	k	-	-	1

Fig. 15. Model architecture. SE is instead of Squeeze-and-Excite. NL is instead of nonlinearity. HS is instead of h-swish. RE is instead of ReLU. NBN is instead of no batch normalization. s is instead of stride.

Batch size	32
Classes	20
Epoch	500
Optimizer	Adaptive Moment Estimation (Adam)
Classifier activation	Softmax

Fig. 16. Training specifications.

Training	640 photos (per class)	64 %
Validation	160 photos (per class)	16 %
Testing	200 photos (per class)	20 %

Fig. 17. Train-validation-test split ratio.

F. Psychosocial in Application

History screen, overview screen and ranking screen were used psychosocial to design the mobile application interface, history of information displays the past performance in details for user which user can compare themselves in today and previous day. Overview screen presents overview score of users in each category which help them to change their behaviors correctly. Also, it was 3 colours to represent different levels of their performance and advice message, these two parts will encourage user to improve their daily activity. Ranking using quintile, appeared in star level let user compete with other by not seeing others score as shown in Fig. 18.

Fig. 18. Psychosocial applied in mobile application interface.

III. DEVELOPMENT RESULT

A. Test case

The results of the system were evaluated by test case approach by running the system following test case then validate the result. The devices used for validating application are Samsung A01, Samsung A7, Samsung A30, Samsung A51, iPad 2017, and iPhone XI pro. The result of application test case is shown in Fig. 19. For web evaluation used Asus ROG Zephyrus M GU502GU-AZ080T Glacier Blue Edition and MacBook pro 2017. The result of web test case is shown in Fig. 20. Note that image classification feature timing depends on device processor.

Test case in Application	result
1. Register feature	✓
2. Login feature	✓
3. Edit profile feature	✓
4. Log out feature	✓
5. Image classification feature*	✓
6. Record food information	✓
7. Scoring food information	✓
8. Add and labelled un-scored food to database	✓
9. Record exercise information	✓
10. Scoring exercise	✓
11. Record sleep information	✓
12. Scoring sleep in formation	✓
13. Record blood glucose level (mg/dl)	✓
14. Display history feature	✓
15. Display overview in 7 days	✓
16. Giving feedback	✓
17. Ranking feature	✓
18. Display ranking History	✓

Fig. 19. Mobile application test case.

Test case in Web	result
1. Add menu and score feature	✓
2. Edit score feature	✓
3. Delete score feature	✓
4. Display score menu and un-scored menu separately.	✓
5. Display data of all user	✓
6. Display mean of data	✓

Fig. 20. Web application test case.

B. User Interface

User interface in both mobile and web application are following from mock-app design and show as expect (Fig. 21.). there is a slightly different interface between device due to device's screen size.

Fig. 21. example of mobile and web application interface.

C. System usability scale (SUS)

System usability scale (SUS) is used to evaluate usability of mobile application. We tested the mobile application with 10 elderly patients with diabetes. The results of SUS are shown in Fig. 22. From SUS score that more than 68, it is determined that a mobile application is above average.

SUS score	83.25
SUS grade	A
Learnability	86.25
Usability	82.5
Cronbach's alpha	0.9747
Standard deviation	0.60

Fig. 22. SUS results.

D. Image Classification Accuracy

In this project, there is an image classification feature helping in classify name of cuisine that received from users. MobilenetV3 (small 1.0) was selected as the pre-trained model. After training the dataset of 640 images per each 20 classes, the training and validation accuracy are shown in Fig. 23. while Fig. 24. summaries trained model feature and testing accuracy.
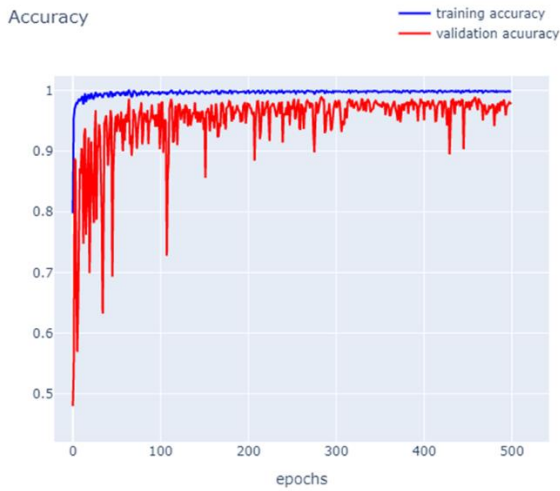
Fig. 23. Model accuracy.

Accuracy	81.12%
Model size	10 MB
Computation time (Samsung A30), (iPhone11 Pro)	16.33 s ± 0.5, 11.67 s ± 0.5,
Total no. of parameters	2,554,968

Fig. 24. Model features.

E. Standardized User Experience Percentile Rank Questionnaire (SUPR-Q)

Standardized User Experience Percentile Rank Questionnaire (SUPR-Q) with net promoter score (NPS) is used to measure quality of website by user experience. This test was applied with our web application tested by 10 medical staffs, nutritionists and related experts. The results of SUPR-Q are reported in Fig. 25.

SUPR-Q	mean	SD
Overall score	86.625	0.60
Cronbach's alpha	0.879	
Usability	92.00	0.48
Trust	87.00	0.64
Loyalty	79.50	0.69
Appearance	88.00	0.61

Fig. 25. SUPR-Q results.

IV. CONCLUSION

This project is divided in 2 applications; mobile application for diabetic patients and web application for medical staff which data is linked to two application by database. Also, the mobile application is written by 1 code using react native expo for be available in both IOS and android. A mobile application is in Thai language and Thai cuisines are available to be fill-in through the system. Plus, the application design is under psychosocial theory which help patient improve their cure methodology by themselves. Image classification will help user fill-in menu from picture which its accuracy is 81.12%. SUS score of mobile application is 83.25 which more than 68. Also, SUPR-Q overall score of web application is 86.6 which accept that the website is good enough for medical staffs. The comparison of our application and other application is shown in Fig. 26.

	Our application	Other application
Including dietary, exercise, sleep and blood glucose level information in one application	✓	
Thai cuisine and Thai language	✓	✓ (some)
Have AI feature to classify food image	✓	
Show history or overview score	✓	✓ (some)
Ranking score with others	✓	✓ (some)
Unlimited time for data collection	✓	
Have web application for medical staff	✓	

Fig. 26. Comparisons of our application and other application.

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