UNIVERSITY OF TROMSØ UIT

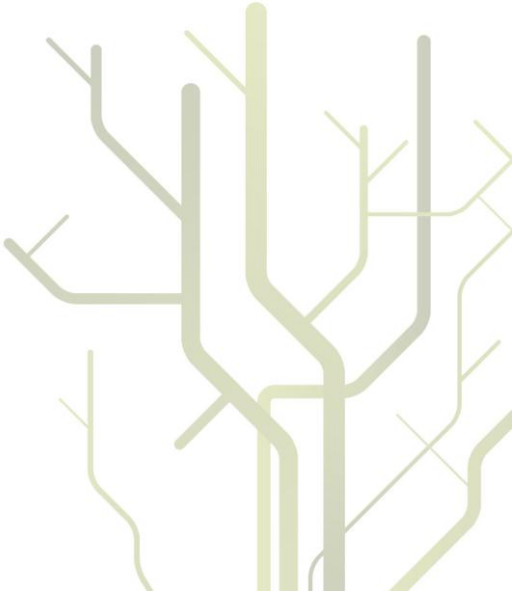
FACULTY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF COMPUTER SCIENCE

Smart Carb

A mobile nutrition self-management application for people with diabetes

Eunji Lee

INF-3997
Master's Thesis in Telemedicine and e-Health
July, 2011



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Dedication

To
My Parents

Preface

According to Article 25 in 'The Universal Declaration of Human Rights' which was adopted and proclaimed at the General Assembly of the United Nations on 10th of December in 1948, health and wellbeing are regarded as one of the most important basic human rights:

"Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control." [(1)

As it mentioned in Article 25, medical care is one of the major factors for healthy life, and everybody has right to receive proper medical treatment to secure themselves from sickness.

There are people who have problems with getting medical support, for example patients living in countryside. I wanted to learn how to help them using information technology. In addition I was interested in study how to maximize the benefit to the patients from continually advancing information technology. That's why I enrolled 'Master's program in Telemedicine and E-health', and my thesis project started from these points.

Nutrition management has been regarded as one of the most difficult challenges for people with diabetes. In the diabetes care routine, diet is a particularly problematic regimen (2), (3), (4),(5).

This MSc project in Telemedicine and e-Health is part of on-going research in the Life Style project "The Few-Touch application" which focuses on development of mobile phone based self-help tools for people with diabetes. The project is funded by the Research Council of Norway, Tromsø Telemedicine Laboratory (TTL), and Norwegian Centre for Integrated Care and Telemedicine (NST), a branch of the University Hospital of North Norway (UNN).

A mobile phone-based system for supporting lifestyle changes among people with Type 2 diabetes has been designed and tested on a cohort of 12 patients (6). The Few-Touch application comprises a blood glucose monitor connected to a Bluetooth adapter, a tailor-made step counter, a nutrition habit registration system, and a system for practical tips.

Feedback received from participants after a 6-month trial of the 'Few Touch Application', indicates that there is need for rich food-relevant information which is more practical to their use. Thus, I decided to enhance the functionality of the nutrition module. I have named my solution "SMART CARB".

‘SMART CARB’ is an android-based smart phone application. It was developed to give people with diabetes help for their self-management of nutrition. It provides detailed food-relevant information in a simple way to think about and adapt.

I appreciate the financial support from TTL, NST and the university – laptop, smart phones and travel expense support have allowed interviews with Norwegian and South Korean study subjects.

I would like to thank my supervisor, Professor Gunnar Hartvigsen for his advice and guideline. This project would never have been done without his expertise, and support. I appreciate the time he took in his busy schedule for advising me.

A special thanks to my mentor, Geir Østengen, for his encouragement and advices based on his own experience. Without his guidance and support, this project would never have been a success.

To my co-supervisors, Eirik Årsand and Naoe Tatara - thank you for the advices and feedback.

A great thank to Medical Doctor Ms. Yoon-hee Choi in Seoul St. Mary’s hospital for strong support and guidelines for interviews with Korean subjects, and thank to Hilde Gaard and Ragnhild Varmedal for helping with the Norwegian subjects.

I also thanks to Kirsti Bjerkan, a Norwegian nutritionist for the practical information and advices about nutrition management of diabetes.

Finally I thank my parents, Munrea Lee and Geumja Jin, and my sister Eunmi Lee and my brother Yongmin Lee for their moral support and constant cheering and encouragement through phone calls.

Most importantly I thank God!

Tromsø, July 23 2011

Eunji Lee

Abstract

Purpose
The purpose of this thesis research is to develop a mobile phone application which can help people with diabetes make better choices in selecting food items and improve their nutrition management.

Motivation
Feedback from users of the 'Few Touch Application' (a previously developed self-help tool for people with diabetes), suggested that some improvements were needed in the nutrition management module. With rough categorizing (six different categories - low carbohydrate snack, high carbohydrate snack, low carbohydrate meal, high carbohydrate meal, low carbohydrate drink, and high carbohydrate drink) by low and high carbohydrate, users didn't know where the food they consumed should be placed. In addition they wanted to have more detailed food information than just categories. Moreover the users wanted to know more about the influence of changing their food intake habits on their blood glucose levels.

Methods
'Smart Carb', a simple application was developed to solve this problem and tested by 27 Type 2 diabetics in two countries. The application was developed in Android OS environment. Visual blocks programming language was used to developed the system through 'App inventor' tool provided by Google. Questionnaires, presentations about 'Carb counting' and 'Smart Carb', usability test and verbal interviews were conducted in Norway and South Korea. To analyse the result of the tests comparative method and qualitative method were used.

Results
The Norwegian participants who had experience with the 'Few Touch application' expressed a strong willing to use this application. However the Korean participants who did not have experience with such this kind of application and the smart phone itself, were little bit sceptical or afraid of using this application. Most of the participants agreed as to the importance of tracking the amount of carbohydrate intake, and expressed difficulty in estimating the amount of carbohydrate in food items. Therefore they wanted to have a tool to help them to estimate carbohydrate amounts.

Conclusion
The effectiveness of this system was found to have a positive impact to the participant, specifically the Norwegian participants who had experience with a mobile diabetes self-help tool. A strong wish to integrating it into 'Few Touch application' was found as well. Automatic measuring of blood glucose, history function, auto-recognition photo are suggested to be adopted to the application for future research.

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Chapter 1

Introduction

1.1 Background and motivation

Diabetes is one of the most wide-spread chronic diseases that can cause many different life-threatening complications. Acute complications of diabetes are diabetic ketoacidosis and hyperglycemic hyperosmolar syndrome and they require immediate treatment. If there is no proper treatment, in extreme cases, patients can lose consciousness or even lose their lives. Microvascular complications such as retinopathy, nephropathy, neuropathy, etc., and vascular complications such as coronary artery disease, peripheral arterial disease and cerebrovascular disease, are some examples of chronic complications of diabetics.

However if the patients manage their diabetes well, they can avoid these frightening complications. This means if blood glucose level is well managed, the possibility of complications from diabetics will be reduced.

Medical recommendations for both Type 1 and Type 2 diabetes include nutrition, physical activity, and medications if necessary. These are the main factors that affect the blood glucose level. Of these three factors, patients regard following nutrition recommendations as especially challenging, due to their lack of knowledge, understanding or skills concerning diet management. Ahlgren et al. (7) said that in diabetes management, adjusting dietary lifestyle is often tough for people with diabetes. According to the findings by Nafelkerk et al (8), 'Lack of knowledge and understanding of a specific diet plan' was ranked top as the perceived barrier by twenty-four subjects with Type 2 diabetes.

Mobile terminals are considered to have a high potential as a platform for supporting tools for people with diabetes' self-management, due to their portability and having emerging technologies embedded (9).

An innovative and well-organized system to manage blood glucose level was developed by Årsand (6). The system is called 'Few touch application', and this mobile phone based system comprises a blood glucose monitor connected to a Bluetooth adapter, a tailor-made step counter, a nutrition habit registration system, and a system for practical tips. A new sensor system has been designed for fully automatic transfer of blood glucose values, as well as a sensor system for fully automatic gathering and transfer of step counter data, and a module

that requires less time and effort for recording food habits than current mobile systems. The modules have been designed to interact with a touch-sensitive smartphone. The developed sensor system for fully automatic transfer of blood glucose values has been subjected to two clinical trials, the first of which revealed that the automatic functionalities are crucial for the use of the system. The sensor system for physical activity was therefore designed with a similar degree of automation for the data transfer, and even performs the data recording without needing attention from the user as long as the sensor is attached to the user (6). The application for recording food habits requires only two touches from the user's finger to accomplish basic data capture. Feedback based on the half-year user intervention indicates good usability of the tested systems, and several of the participants adjusted their medication, food habits and/or physical activity due to use of the Few Touch application (6). The system provides users with feedback on how they perform in relation to their own personal aims or general recommendations regarding nutrition habits, physical activity, and blood glucose levels.

Through the 'Few touch application' system, users could control their physical activities and experience its influence on blood glucose level so that they could go a step forward to self-management of diabetes. Recording food habits by registering which food they had using six different categories (low carbohydrate snack, high carbohydrate snack, low carbohydrate meal, high carbohydrate meal, low carbohydrate drink, and high carbohydrate drink) encouraged the users to eat more fruits and vegetables (10) and led the users to eat less carbohydrate-rich food (11), so that the users could manage their disease more actively.

According to the feedback from the users who tried this system, more detailed information about food which they ate was needed. In addition, the users wanted to know more about the influence of changing their food intake habits on their blood glucose levels. With the rough categorizing by low and high carbohydrate, users didn't know where the food they had should be placed ("Jeg finner ikke hvor jeg må registere det som jeg har spist med 'Few Touch Application'." - feedback from individual interviews). For this reason, some of them avoided using the nutrition-recording part in the 'Few touch application' ("Mat program i 'Few Touch Application' er elendig. lav karb og høy karb er ingenting. Jeg kuttet å bruke det med en gang." – feedback from individual interviews).

1.2 Scope and research problem

This project was started to improve the above-mentioned limitation and challenge.

The goal of this master's project is to develop a mobile phone-based application with which people with diabetes can record their food habits and see how theses habits affect their blood glucose levels. It is expected that the users can learn from their experiences how they should change their food habits and manage their nutrition themselves.

The main research problem of this thesis can be stated as follows:

“How can a mobile phone application help people with diabetes to make the best choice in selecting food for their proper nutrition management?”

A. Information providing

The information that this application provides, should include rich enough food information so that they can look up the actual and practical information about the food they had.

The information should not be too much or too complicated so that the users are not confused or overwhelmed by the amount of information.

Question 1: To improve self-nutrition management for people with diabetes, what kind of information should be included in the application?

B. Categories

Too rough or too ambiguous categories can make it difficult for the users to figure out the food category after a meal. On the other hand, if there are too many sub-categories, it may just increase the number of clicks and the time to reach the actual information.

The categories of food items should be easy to follow enabling users to find the food types that they are actually looking for.

Question 2: How can the food items be categorized in a simple way in order to find relevant information quickly?

C. Food item

Even though the system is well designed, if there is no relevant information that is useful for the users and cannot benefit the user, it will be difficult to say that the system is any good. The food information in this application should be based on food items that the users normally eat.

Question 3: Which food items should be included in this application for the users to use this application in a practical way?

D. User interface

The user interface should be designed to help the users operate the system easily. Simple words, illustrations or pictures will reduce the time to make the users understand the concept of this application and to learn how to use this application.

Question 4: How should this application be designed to have a user-friendly interface which can be used, naturally and unobtrusively easily in real life situations?

E. Self-management

The system should guide people with diabetes how to manage their food habits. The system should not force the users to change their food habits in a particular way. It should encourage the user to think about the relationship between their food habits and their blood glucose levels, so that they can help themselves improve their nutrition management based on the information which this application provides.

Question 5: How should this application motivate the users to persuade them to change their habits for better nutrition management?

1.3 Summary of Goals

The goals for this thesis project can be summarized like below. The goals are based on the sub-problems which were discussed in section 1.2

A. This thesis should investigate what kinds of food information are the most valuable to be presented in a mobile terminal-based tool for diabetes diet management. The information should be rich-enough and not too much at the same time to improve the user's self-management.

B. This thesis should demonstrate how to categorize food items in a way that is easy for the users to follow and enable them to quickly find the food items they are looking for?

C. This thesis should describe how the food items were selected to enhance the application's practicality.

D. This thesis should show the procedure of designing a system that has a user-friendly interface for the people with diabetes.

E. This thesis should demonstrate a system that guides people with diabetes to change their dietary habit for better nutrition management

1.4 Assumptions and Limitations

This project focuses on helping the following groups of people through education:

- The people who are newly diagnosed with diabetes so that there is an obvious need to change their food habits

- The people with diabetes who have problems controlling their blood glucose levels due to poor nutrition management

- The people with diabetes who have problem with changing their food habits and wish to stimulate themselves to keep the proper nutrition management

Limited time was the main limitation of this thesis project.

1.5 Methods

The work presented in this thesis was conducted in the following order:

a. State of the art of 'mobile terminal-based diabetes diet management tools'

b. Developing a paper and excel prototypes

c. Meeting with a nutritionist

d. Improvement of the prototypes

e. Developing an android application

f. Interviews with Norwegian subjects

g. Interviews with Korean subjects

An engineering approach, which is explained by Denning et al. (12), was used to construct a prototype and demonstrated the solution to solve the problems.

First to figure out the current status and to obtain future prospects, academic literatures about mobile terminal-based tools for diabetes diet management were reviewed and findings are summarized.

After the information would be displayed by the application was decided, paper prototypes and excel prototypes were developed based on the type of this information.

A meeting with nutritionist was held to get feedback about the developed prototypes and to discuss the points that were needed to improve.

The prototype was improved based on the advices from the nutritionist. Then with the improved prototype, an android phone based application was developed.

To compare the perception of this application from an international point of view, verbal interviews and usability tests were conducted in Norway and South Korea. Interviews were held with this android mobile phone application by showing how to use the application first and then letting them to try the application. Seven and twenty participants with Type 2 diabetes were involved in individual interviews in Norway and in South Korea, respectively. The age range of the subject group was between 40 and 80 years old. To see the condition of their nutrition management and their level of satisfaction, a questionnaire was also conducted at the same place before interviews.

Because of the different food culture and dishes which are normally served in Norway and in Korea, different food items were included into each application. Different ways to register the amount of food were also used to fit the two different food cultures. However, these two applications were constructed with the same concept to make the user think about food habits. The feedbacks from participants were obtained in the same way.

1.6 Significance and Contribution

The main contribution of this thesis is the first attempt to develop and test a nutrition self-management mobile phone based application for people with diabetes in Norway and in South Korea. The subjects' condition of nutrition management and level of satisfaction with it in these two countries was investigated also before the tests were held. This research provides overview of perception by people with Type 2 diabetes about the importance of nutrition self-management. Results show how they can benefit by using a simple smart phone based nutrition self-management application which enables the users to learn how they should change their food habits for better nutrition management further for better blood glucose level controlling.

1.7 Organization

The rest of this thesis is organized into the following chapters:

Chapter 2. Theoretical Framework
This part gives an overview about diabetes, its prevalence and cost, and self-management. Review of mobile terminal-based tools for diabetes diet management is given as state of the art in this part. In addition carbohydrate counting for diabetes nutrition management is introduced.

Chapter 3. Materials and methods
This chapter describes the research methods that are used in this project for developing, implementing and evaluating.

Chapter 4. Requirements and specification
This chapter explains the requirements and specification of this project. Also it is explained why some of requirements had been implemented.

Chapter 5. Design
This chapter shows the process of design, structure of the system, how the final model has been improved.

Chapter 6. Implementation
This chapter includes the process of developing application such as how to implement the requirement and specifications into the real system, etc.

Chapter 7. Test and result
This chapter describes the actual tests that were conducted, and analyses the individual interviews, questionnaires, usability tests.

Chapter 8. Discussion
Findings are discussed in this chapter. The result of the test are also analysed and interpreted in this chapter.

Chapter 9. Conclusion and future work
Conclusion of this research and suggestions for potential future work were offered in this chapter.

Chapter 2

Theoretical Framework

2.1 Basic knowledge about diabetes

2.1.1 What is Diabetes?

When a person does not produce enough insulin or there is no response to the insulin produced by the body's cells, resulting in the person having high blood glucose, we call this disease diabetes (13). Diabetes is metabolic disease, and several symptoms occur due to the high blood glucose.

2.1.2 Types of diabetes

A. Type 1 Diabetes

Type 1 diabetes is also called insulin-dependent diabetes or juvenile diabetes. Type 1 diabetes patients cannot produce any insulin so we call it insulin-dependent diabetes. The reason why we call Type 1 diabetes juvenile diabetes/early-onset diabetes is that most of the Type 1 diabetes appeared before age 40, when the patients are children, teenagers or young adults (14). Among the diabetes patients, there are just 5 to 15 % of diabetics who are diagnosed as Type 1 diabetes (15). The treatment for Type 1 diabetes includes injective medicine, taking insulin, control blood glucose, proper dietary, physical activity, and taking aspirin-for some patient (14).

B. Type 2 Diabetes

Type 2 diabetes is also called noninsulin-dependent diabetes or adult (late)-onset diabetes. Some insulin can be produced by Type 2 diabetes patients, however the reaction of their body cells to insulin is not good enough or the insulin does not work well, and therefore we call it noninsulin-dependent diabetes (15). The reason why we call Type 2 diabetes adult- or late- onset diabetes is it occurs often in older people 40 and above (15). About 85 to 95 % of the whole diabetes is Type 2 diabetes (15). The treatment for Type 2 diabetes includes control blood glucose level, proper dietary, physical activity, using medicine, and taking

aspirin-for some patients (14).

C. Gestational diabetes

When women cannot produce enough insulin due to pregnancy, we call it gestational diabetes (15). After the women deliver their babies, the symptoms disappear naturally (14). However, there is high risk not only for the women but also for the babies to develop Type 2 diabetes later (16). Between 2 to 5 % of all pregnancies can develop to gestational diabetes (15). For the treatment, self-care dietary is vital (14).

A healthy balanced diet is one of the important treatments for all the types of diabetes. We must remember that the lack of proper treatment can cause many different complications. Hypoglycaemia, diabetic ketoacidosis or nonketotic hyperosmolar coma is the examples of the acute complications, and cardiovascular disease, chronic renal failure and retinal damage are the examples of serious long-term complications of diabetes (13).

2.1.3 Symptoms of diabetes

High blood glucose makes the patients thirsty (polydipsia) and it causes over-intake of water so that they need to urinate more frequently (polyuria). In addition, patients feel hunger (polyphagia) because the glucose is discharges through urine from their body. And also the patient loses weight.
Different complications can be developed if high blood glucose in the patient's body remains for a long term, for example, retinopathy (the person can be blind), renal dysfunction (can cause dialysis), and it leads high risk of cardiovascular disease.

2.1.4 Prevalence

It is not difficult to find people with diabetes nowadays. In my case, one of my cousins is Type 2 diabetic. I have met more people with diabetes at school and also outside. It is a big issue that the number of people with diabetes is growing rapidly.

Wild et al. (17) predicted that the prevalence of diabetes will rise up from 2.8% in 2000 to 4.4% in 2030 for all age-groups worldwide, and projected that the total number of people with diabetes would rise from 171 million in 2000 to 366 million in 2030 through the world. Figure 1 shows the estimated numbers of people with diabetes in the world in 2000 and in 2030 according to the each age group.

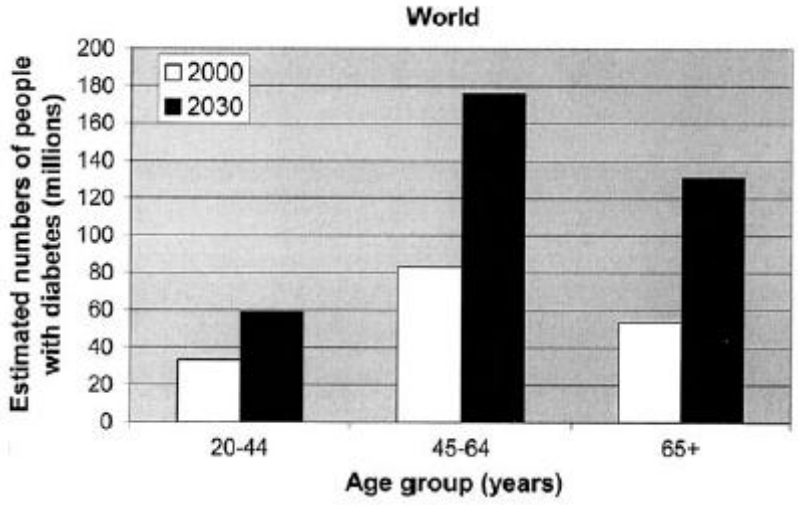

Figure 1. Estimated number of adults with diabetes by age-group, year in the world (17)

Shaw et al. (18) estimated that the number of adults diabetics (aged 20-79 years) will increase 69% in developing countries and 20% in developed countries between 2010 and 2030. The estimated numbers of people with diabetes in different regions for 2010 and 2030 and the anticipated growths are presented in Table 1 together with the prevalence of diabetes.

Table 1. Prevalence of diabetes and estimated diabetes numbers by region among adults aged 20–79 years for the years 2010 and 2030 (18)

	2010			2030			2010/2030
	Total adult population (000s)	No. of adults with diabetes (000s)	Diabetes prevalence (%)	Total adult population (000s)	No. of adults with diabetes (000s)	Diabetes prevalence (%)	Increase in the no. of adults with diabetes (%)
Africa	379	12.1	3.8	653	23.9	4.7	98.1
EMME	344	26.6	9.3	533	51.7	10.8	93.9
Europe	646	55.4	6.9	659	66.5	8.1	20.0
N America	320	37.4	10.2	390	53.2	12.1	42.4
S & C America	287	18.0	6.6	382	29.6	7.8	65.1
S Asia	838	58.7	7.6	1200	101.0	9.1	72.1
W Pacific	1531	76.7	4.7	1772	112.8	5.7	47.0
World	4345	284.8	6.4	5589	438.7	7.7	54.1

[a] Prevalences for each region are standardized to world age distribution of that year.

There can be several reasons why the number of people with diabetes is increasing. The reasons can be, for example, because the number of total population is growing, and the number of people with obesity is increasing, and also due to aging, urbanization and physical inactivity (17).

The number of people with diabetes is higher in women than men, however men have a greater prevalence of diabetes than in women, and the most rapidly increasing age group in the world is age group higher than 65 years old (17). In my opinion, it is important to

remember that not only obesity prevalence but also aging is one of the biggest factors to increase diabetes prevalence.

We need to focus on the fact that increasing diabetes prevalence will raise the proportion of death due to the cardiovascular disease and other complications associated with diabetes.

2.1.5 Cost

Because diabetes can cause many different serious complications, it can be regarded as a life-threatening illness. Therefore it is important that the patients with diabetes check their status occasionally and receive proper medical treatment which corresponds with their condition.

Jonsson (19) estimated that EUR 2834 is the average annual direct cost of Type 2 diabetes per person in eight European countries (Belgium, France, Germany, Italy, the Netherlands, Spain, Sweden and the United Kingdom) in 2002.

According to the paper 'The Direct Medical Cost of Type 2 Diabetes', Brandle et al. (20) argued that $1,700 and $2,100 are the average annual direct medical costs for white men and women in the U.S. in 2003.

Included in the above costs are the costs for diabetes complications such as microvascular, neuropathic and cardiovascular, which constitute the greatest portion in the total cost for diabetes. A large portion on the direct medical costs of Type 2 diabetes is from diabetes complication and insulin treatment (20). Brown et al. (21) found that the cost for Type 2 diabetes per-person grew by more than 50% after cardiovascular complications appeared, and it increased up to 360% more after major cardiovascular events. The cost was also increased by 65% due to abnormal renal function and by 771% due to end-stage renal disease (21). In the United States, diabetics use 1 in every 7 dollars on healthcare because of the complications related to diabetes (22).

The diverse late complications which are related to diabetes have the largest impact on cost of care for Type 2 diabetics and this makes Type 2 diabetes one of the most high-cost and burdensome diseases in the world (19).

As I mentioned before, the prevalence of diabetes is anticipated to increase. And as the prevalence grows, the cost of diabetes is also expected to increase naturally. The cost for diabetes epidemic is huge both in human cost and economic cost (17).

2.2 Diabetes and nutrition self-management

2.2.1 Patient self-management and self-efficacy

Patient self-management is the term used when a patient takes a more active role in coping with the disease. It is natural that the treatment can be more effective, when the patient knows his/her illness better and can manage it. However it should be under the condition that the patient has correct knowledge of their disease.

Which diseases specially can benefit or and have advantages from patient self-management? When we think about the characteristics of chronic disease, there is a key to answer this question. Chronic disease means a recurring disease which is the opposite from acute disease. This means patients have coped with the disease since they first got diagnosed and will cope with it continuously. This means coping with chronic disease can be a part of the patients' life, and it is crucial for patients to cope with their chronic disease by themselves in their life. Therefore patient self-management is important for the patients who have chronic disease.

For those with chronic disease, patient self-management is especially important because the person who can be accountable for his or her everyday care over the length of the disease is only the patient (23). Therefore, we can say that patient self-management is a lifespan task for those patients who have such chronic conditions.

LeFort et al. (24) have proved the effectiveness in self-management of chronic disease. In a range of chronic conditions, self-management possibly will not only improve outcomes but also save costs (25), (26). Diabetes is one of the most wide-spread chronic diseases.

Self-efficacy is one of important outcomes brought by patient self-management. Through patient self-management, especially by solving problems, patients themselves can achieve self-efficacy.

Self-efficacy means "confidence to carry out a behaviour necessary to reach a desired goal (25)", and in this case, "a patient's level of confidence that he or she can perform a specific task or health behaviour in the future (27)". Self-efficacy is the most predictive variable of enhancements in patients' functional condition (28), (29), (30), (31), (32), (33), (34).

2.2.2 Self-management in nutrition for people with diabetes

Problem-solving is the core in the patient self-management. When patient-identified problems are solved successfully by patients, self-efficacy is enhanced (25).

Nutrition, physical activity, and medications if necessary, are the main factors which influence the people with diabetes' blood glucose levels. These three factors are included in

medical recommendation in both Type 1 and Type 2 diabetes self-management. However, for the people with diabetes, nutrition management has been addressed as the most difficult task. Diet is a particularly challenging in diabetes care routine (2), (3), (4), (5). Changing dietary requirement is often difficult for people with diabetes (7). Nutrition management has been perceived as the most difficult barrier by people with diabetes (8).

Mobile terminals have strong portability and emerging technologies that can support people with diabetes's self-management (9).

2.3 State of the art

This part shows review of academic literatures about mobile terminal-based tools for diabetes diet management.[1]

2.3.1 Purpose

Changing dietary habits is one of the most challenging tasks of diabetes self-management. Mobile terminals are increasingly used as platforms for tools to support diet management and health promotion. Literatures describing mobile terminal-based support tools for management of diabetes which is focused on diet were investigated so as to be state-of-the-art.

2.3.2. Data sources and search criteria

Electronic databases of PubMed (National Library of Medicine and National Institute of Health), ACM (Association for computer machinery) digital library, and IEEE (Institute of Electrical and Electronics Engineers) Xplore were searched to find relevant literatures. Searches were conducted in September 2010.

Following exclusion criteria were applied: (i) papers not written in English; (ii) papers of which full text was not available; and (iii) review articles. Finally, the relevance of each publication was examined by reading the abstract and the whole text if needed. The following data were extracted from the final selected papers: study design, type of mobile terminal used, targeted population, main purpose of the tool used or developed, significant features of the tool regarding diet management, and the findings for each study.

2.3.3. Search methods

[1] This state of the art has been accepted as a full paper in 'International Conference of the European Federation for Medical Informatics 2011(28.08-31.08, Oslo)'.

Combination of keywords was used to search the relevant literatures by multiple steps. Firstly 'Food/Nutrition/Diet' plus '(Cell/Mobile) Phone/personal digital assistant/Handheld' were used to extract relevant studies. Secondly the duplications were eliminated from the result. Lastly the results were extracted by keyword, 'Diabetes' to find comparative resources. Total 27 papers were founded. Table 2 shows the number of hits as the result of searching by the combinations of keywords from each website.

Table 2. The results of data extraction

Database	Keywords	Hits
Pubmed	food + "cell phone"	9
	food + "mobile phone"	17
	food + "personal digital assistant"	18
	food + "hand held"	78
	nutrition + "cell phone"	1
	nutrition + "mobile phone"	15
	nutrition + "personal digital assistant"	13
	nutrition + "hand held"	43
	diet + "cell phone"	0
	diet + "mobile phone"	19
	diet + "personal digital assistant"	25
	diet + "hand held"	29
ACM	food + phone	10
	food + "personal digital assistant"	0
	food + "hand held"	3
	nutrition + phone	1
	nutrition + "personal digital assistant"	0
	nutrition + "hand held"	0
	diet + phone	3
	diet + "personal digital assistant"	0
	diet + "hand held"	2
IEEE	food + phone	36
	food + "personal digital assistant"	0
	food + "hand held"	10
	nutrition + phone	4
	nutrition + "personal digital assistant"	0
	nutrition + "hand held"	0
	diet + phone	7
	diet + "personal digital assistant"	4
	diet + "hand held"	0
Total		252
Diatetes		27

2.3.4 Result

After removal of duplicates, 27 papers were found, of which five met the exclusion criteria. Based on the abstracts, 16 papers were selected as relevant to diet/nutrition. One of these focused on insulin therapy and another was found not much relevant to diabetes, leaving 14 papers for inclusion in this review.

A. Study design

Ten papers (35), (36), (37), (11), (10), (38), (39), (40), (41), (42) describe design and development of management tools for people with diabetes. Of these, seven (35), (37), (11), (10), (38), (39), (40) describe results from evaluation of tools by potential users regarding usability, feasibility and general acceptance; two (41), (42) report results from technical evaluation of tools; the last paper (36) describes the design and development of a tool from a technical perspective. Three of the papers (10), (39), (41) state that the design requirements were obtained by involving people with diabetes as potential users. Evaluations by potential users are conducted through field testing, namely evaluation by use of a tool in the users' real-life setting for a certain period (35), (37), (10), (38), (39) and through laboratory testing (11), (40). Clinical outcomes such as HbA1c were also examined in four studies (35), (37), (43), (44). In three studies described by the four other papers (43), (44), (45), (46), the effectiveness, acceptance and feasibility of commercially available tools based on mobile terminals were investigated in the context of clinical intervention.

B. Type of mobile terminal

Six studies (35), (11), (10), (39), (41), (42) involved mobile phones as the terminal; the others involved PDAs. Windows Mobile-based phones with a touch-sensitive screen were mostly used (11), (10), (39), (41). The commercially available applications were all PDA-based. The year of publication and of each study indicates a clear shift from PDAs to Smartphone-type mobile phones.

C. Target population

Seven studies described in seven papers (10), (38), (40), (43), (44), (45), (46) target people with Type 2 diabetes, and two studies (35), (41) target young people with Type 1 diabetes. The others do not specify the target population, but one study (39) limited participation to people aged over 18.

D. Purpose of the tool

In six studies (35), (36), (10), (40), (41), (43), a tool was used or developed for overall diabetes management with recording of blood glucose values, physical activities and other relevant data in addition to food intake. In the seven studies described in the eight other papers, a tool dedicated to dietary management was used or developed. Several tools are designed for use as a part of telemedicine intervention, where health care professionals

support patients remotely by viewing and analysing the stored data (35), (11), (40), (41). The tools described in six studies (36), (37), (43), (44), (45), (46) give patients nutrition information for a selected food item and/or results of automatic analysis of recorded foods in terms of nutrients and calorie intake; some provide feedback based on the patient's personal information, such as calorie balance or nutrition balance over meals (36), (45), (46). One tool focuses on the glycaemic index (GI) of food items, showing a GI value with an indicator, low, medium or high, for assisting in food choices (44).

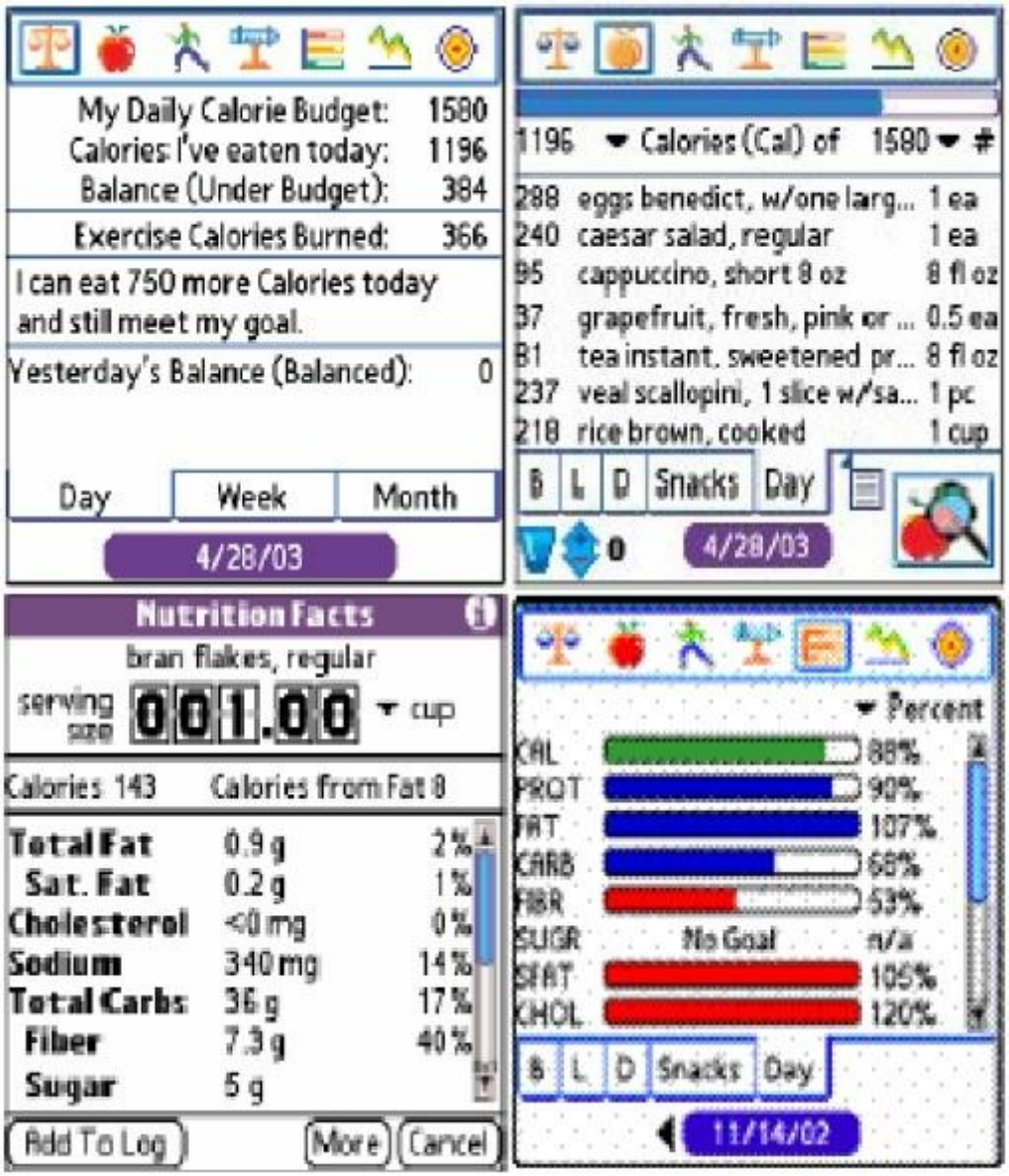

Figure 2. Screens of calorie balance with BalanceLog® software by MicroLife (45)

E. Special features

Recording of food or drink items uses various methods. The most common is to identify items from a database (36), (37), (38), (40), (43), (44), (45), (46). Not all the papers specify the number of items in the database, but one includes more than 4300 items (45), (46) whereas another includes 423 items (38). Portion size can be adjusted in some of these tools (38), (40), (45), (46), and two tools present photographs of food or drink items that can be used as a reference (38), (40). Other methods of recording include free text input (41) and photographing using a camera on a mobile phone (11), (42). The tool described in paper (42) is designed to recognize a food item by semi-automatic analysis of the photo together with contextual information. Meal types, such as breakfast, lunch, or dinner, are also used as data for recording (36), (38), (40), (44), (45), (46), and time for meal intake can also be recorded on two tools (38), (41). Food intake could be recorded into 3 categories like smaller carb meal, usual carb meal and larger carb meal (35). The tool used in two of the studies (11), (10) has only six buttons for the user to select a meal, snack, or drink with high or low carbohydrate content, enabling simple and quick recording in only a few operations. After data entry, this tool shows cumulative totals of foods or drinks recorded by category together with feedback according to personal goals, and smileys when goals are achieved (10).

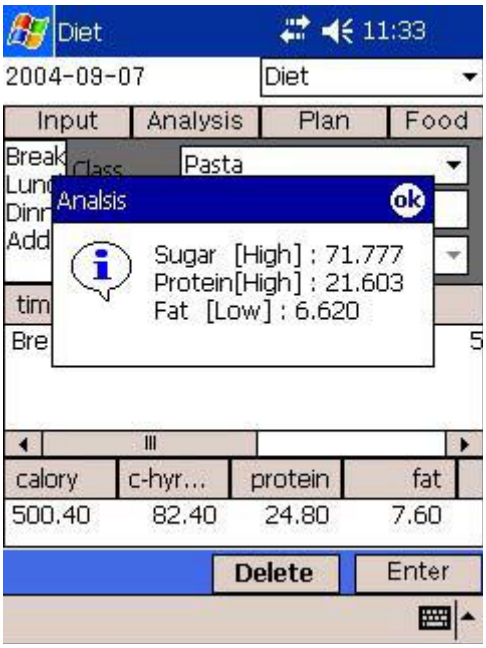

Figure 3. Nutrition analysis screen in PDMS (Personal Diabetes Management System) (36)

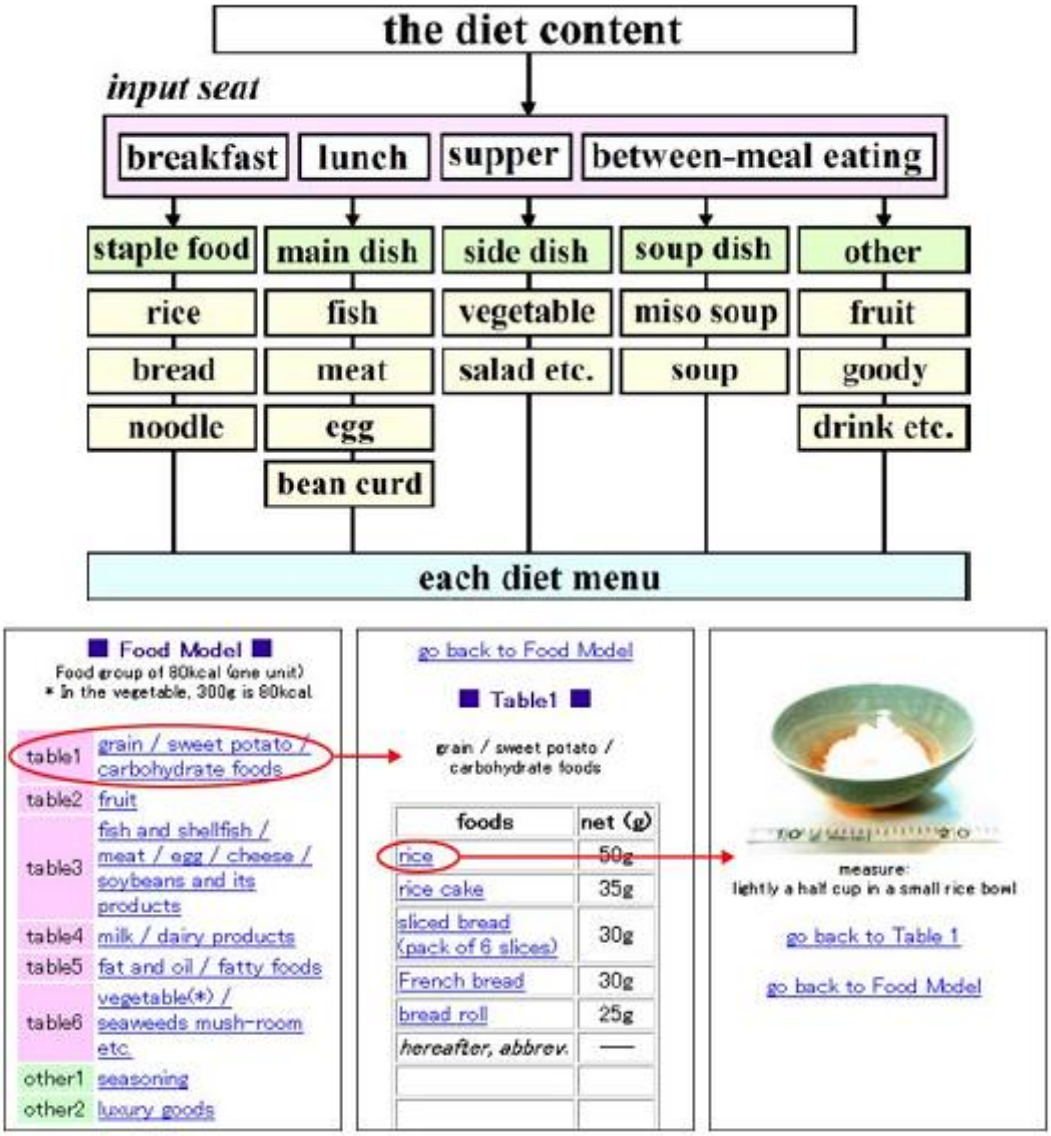

Figure 4. Flow of input and flow of food model reference by Tani et al. (40)

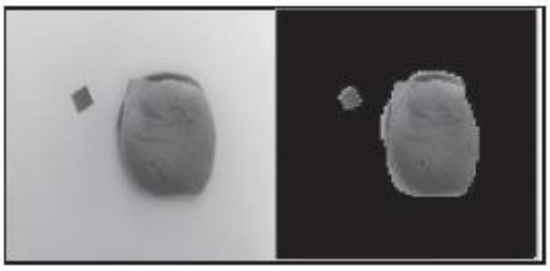

Figure 5. Recognition example of using reference object (42)

Figure 6. Smartphone picture-capture (11)

Figure 7. Picture of dairy screen implemented on the phone by Farmer et al. (35)

Figure 8. Nutrition registration screens in Few Touch Application (10), (11)

One study (39) involves tools designed and developed purely for educational purposes utilizing three types of games incorporating several education theories and customizable functions so that patients can play and learn about diet management.

Figure 9. The mobile video games Hangman, QuizShow and Countdown (left to right) on an iPhone, Windows Mobile and Blackberry by DeShazo et al. (39)

F. Summary of findings

In four of the studies (35), (37), (43), (44) where clinical outcomes are evaluated, it is observed that HbA1c decreased among the participants in the intervention group who completed the study. However, in the study described in (37), decrease in HbA1c is only observed among the group of participants whose history of having diabetes is shorter than the other group. In the study described in (10), the participants improved their nutrition habits, especially intake of vegetables and fruits.

In most of the identified studies, the tools used are generally well accepted by participants in terms of ease of use (37), (11), (40), (43), (44), (45), usefulness, problem-solving capabilities, learning and motivational effects in dietary management (37), (11), (10), (39), (43), (44), (45), and feasibility for patient interventions due to high accuracy and reliability of recorded data (38), (44). It is noteworthy that no drop-outs from the studies due to difficulties in using the tools are reported in the selected papers. However, in the studies described in (39), (45), considerable time was devoted to instructions for use, and the 12 elderly participants without experience in using PDAs or with problems in motor skills remained in the study, but gave up on using the PDA (45). In some studies, consequences such as drop-outs from the study, decrease in use, low use, or negative opinions of the tools were observed – partly due to burdensome or tiresome daily registration (10), (43), (44), (45), apparent improvement in glycaemic control (43), or saturation of effects on diet management (10), or misunderstanding, underestimating importance of self-management or treatment regimens, or limited understanding (45).

Despite the generally positive opinions of the tools, some difficulties in behaviour change are reported in terms of nutrition habit (37) and adherence in self-monitoring of diet (46). Sevick et al. found that adherence to diet self-monitoring is not associated with sociodemographic characteristics, but rather with the level of adherence in the early phase of intervention (46).

Concerning tool features, customization or modification based on personal data or users' skills is considered important and beneficial (11), (39), (44) Timely, automatic and personalized feedback should be incorporated in a motivating and easily interpretable manner (11), (43), (44), (45). A database showing nutrient and calorie content is considered powerful if it contains enough variety and numbers of food and drink items that are familiar to users (11), (44). Simple categorization for recording nutrition habits is well accepted and appreciated for routine use (11), but some participants consider such categorization too coarse (10). Photographs of food and drink items are considered useful, especially if they include a scale or familiar cutlery as a reference of size, for adjusting portion sizes (40). Photographing food and drink items for recording and later consultation is considered practical for occasional use, but not for routine use (11). Educational games are considered most suited for the young population and for short-term use. Thus, the ease and the ability to quickly launch and complete functions are important (39).

G. Discussion

The identified publications show that mobile terminal-based tools have been generally well accepted and shown to be effective for diet management or glycaemic control to a certain degree. For successful diet management, people with diabetes need a good understanding of their diet regimen. In order to make a diet management tool feasible and useful, it should enable recording of food intake in an easy, but accurate enough manner. It should also provide immediate analytical feedback based on personal data in an easily interpretable way, preferably with other data about and exercise so that patients can reflect on their total behaviour. The tool should also include educational materials, with a database of food and drink items familiar to patients. For accurate recording of food quantities, visual reference such as photographs taken using a familiar object to indicate size is considered useful.

From this review, key features to achieve both ease of use and accuracy in recording could not be clearly identified because of the mixed feedback from the participants, the time and effort required for user instructions, and the study designs, which do not compare the different tools in some of the studies. Food recognition by photographing may have a high impact when the technology enables reliable identification. Another challenge is how to design a tool that supports adherence in self-monitoring over a substantial period – long enough for achieving healthy effects. It might not be necessary for a tool to be used permanently, if use of the tool leads to better diet management, but often it needs to be used at least periodically for maintaining awareness of the importance of a healthy dietary regimen. As described in (11), simple and quick registration with immediate feedback would be suitable for routine use, but at the same time a tool should be designed so that it will not

be tiresome or boring. Key features that encourage a wide variety of patients to be continuously engaged in using a tool should be investigated in future research, borrowing knowledge from the field of persuasive technology, human computer interaction, and psychology.

The market for advanced mobile phones, e.g. smartphones, is growing rapidly and a great number of mobile applications are available on the market today. Further research is required to examine such applications to identify key features for design of effective and useful support tools for diet management for people with diabetes – and other disease cases that will benefit from diet management.

2.4 Carbohydrate counting and diabetes nutrition management

2.4.1 Carbohydrate

A. One of our most important main energy sources

The food we eat and drink contains nutrients such as carbohydrates, protein, fat, vitamins and minerals. In the gut, these nutrients are broken down into small units and these units provide energy to the cells in our body.

Carbohydrate intake can vary from 45 to 60 energy percent (E %) in Norway (47). However, according to the KDRIs (Dietary Reference Intakes for Koreans), AMDR (Acceptable Macronutrient Distribution Ranges) from carbohydrate is from 55 to 70 percent of total calories (48).

B. What are carbohydrates?

Carbohydrates are a collective term for simple sugars, starch and dietary fiber. Simple sugars (glucose, fructose, galactose and lactose) are contained naturally in foods such as fruits, berries and milk. Refined sugar (sucrose) is added to many foods like soda, juice, cakes, biscuits and candy. Starch is a plant nutrient and it is found only in foods from plant sources. Cereals, rice, corn and potatoes are the main sources of starch. Dietary fiber is found in rich amounts in cereals, vegetables, fruits and legumes (peas, beans, lentils). It reduces the speed of absorption of carbohydrates.

Eating food items that contain carbohydrates is important. Here are four main reasons which explain why we should intake carbohydrates (49).

1. Carbohydrates provide energy.
2. Carbohydrates provide a good satiety.
3. Carbohydrates can replace fat.

4. Carbohydrates rich foods help vitamins, minerals and dietary fiber to be absorbed in our body.

C. Where can we find carbohydrates?

In Norway

In bread meals (breakfast and lunch), bread and other grain products, milk, juice and fruit are main sources of carbohydrates, and in supper meal (dinner), potato, rice, pasta and bread are major sources of carbohydrates (49).

Figure 10. Examples of nutrition facts which shows carbohydrate amount (Norway)

Table 3. Nutrition information of some food items (Norway)

Matvare	Vann, g	Energi1, kJ	Energi2, kcal	Protein, g	Fett, g	Karbo, g	Fiber, g	Alko, g
Appelsinjuice	88	182	43	0.6	0	10	0.1	0
Brus, med sukker	90	170	40	0	0	10	0	0
Gulløl, 5,7 vol-% alkohol	90	214	51	0.5	0	3.9	0	4.8
Vin, rødvin, 12 vol-% alkohol	89	292	70	0.2	0	0.8	0	9.5
Matvare	**Vann, g**	**Energi1, kJ**	**Energi2, kcal**	**Protein, g**	**Fett, g**	**Karbo, g**	**Fiber, g**	**Alko, g**
Baguett fin, halvstekt type, stekt	34	1100	260	9.9	1.4	50.6	2.5	0
Berlinerbolle, kjøpt	31	1356	323	6.3	13.6	42.8	2.2	0
Birkebeinerbrød, kjøpt	36	1015	240	8.3	2.8	42.4	6.2	0
Brownies med sjokoladeglasur, kjøpt	15	1761	421	4	20.2	54.2	3	0

In South Korea

'Rice, barley, wheat, corn, potatoes, sweet potatoes, bread, spaghetti and noodles represent starch-containing foods in Korean dishes. Fruit represents fructose-containing foods. Milk and dairy products represent lactose-containing foods. Candy, chocolate, sugar, syrup, etc. represent monosaccharide and sucrose-containing foods. (50)'

Figure 11. Sugar free juice (South Korea)

Figure 12. Example of nutrition fact of a Korean food item

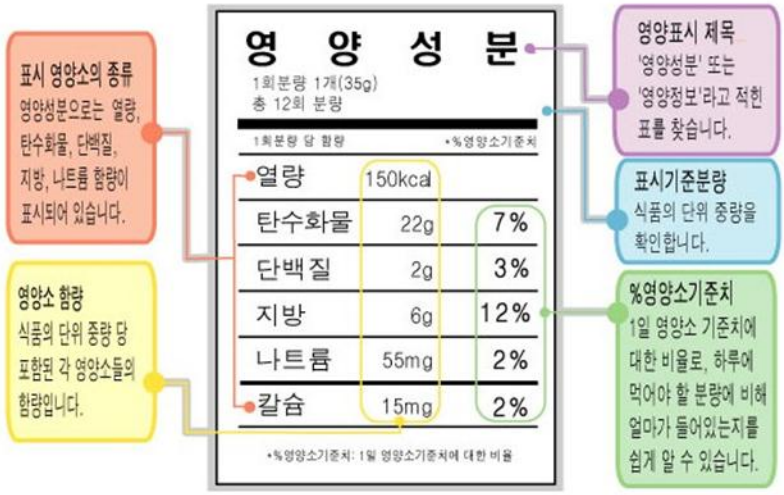

Figure 13. Explanation of each part in nutrition fact label (Korea)

Table 4. Nutrition information of rice and fried rice (Korea)

재 료 명 : 쌀밥 검 색

재료명	DB source	CODE	energy (Kcal)	water (g)	CHO (g)	sugar (g)	fiber (g)	prot (g)	fat (g)	SFA (g)	MUFA (g)
쌀, 쌀가공식품, 멥쌀, 논벼, 밥/죽류, 쌀밥, 백미	KOR	101199	136,0	63,6	33,2				3,0	0,1	0,16
쌀, 쌀가공식품, 멥쌀, 논벼, 밥/죽류, 쌀밥, 백미, 새추청벼	KOR	101203	152,0	63,5	33,8				2,5	0,1	
쌀, 쌀가공식품, 멥쌀, 논벼, 밥/죽류, 쌀밥, 백미, 수라벼	KOR	101202	159,0	61,8	35,7				2,4	0,02	
쌀, 쌀가공식품, 멥쌀, 논벼, 밥/죽류, 쌀밥, 백미, 일품벼	KOR	101201	156,0	62,6	34,6				2,6	0,05	
쌀, 쌀가공식품, 멥쌀, 논벼, 밥/죽류, 쌀밥, 백미, 추청벼	KOR	101200	150,0	63,8	33,7				2,4	0,03	
쌀, 쌀가공식품, 멥쌀, 논벼, 밥/죽류, 쌀밥, 찰분도미	KOR	101198	168,0	60,0	36,7				2,6	0,5	0,16
쌀, 쌀가공식품, 멥쌀, 논벼, 밥/죽류, 쌀밥, 현미	KOR	101197	150,0	58,5	37,3				3,3	0,2	0,3
쌀, 쌀가공식품, 멥쌀, 밭벼, 쌀밥, 백미	KOR	101238	168,0	60,0	36,1				3,5	0,3	
쌀, 쌀가공식품, 멥쌀, 밭벼, 쌀밥, 찰분도미	KOR	101237	168,0	60,0	35,7				3,6	0,5	
쌀, 쌀가공식품, 멥쌀, 밭벼, 쌀밥, 현미	KOR	101236	165,0	59,8	34,4				4,2	1,0	

재 료 명 : 볶음밥 검 색

재료명	DB source	CODE	energy (Kcal)	water (g)	CHO (g)	sugar (g)	fiber (g)	prot (g)	fat (g)	SFA (g)	MUFA (g)
볶음밥, 냉동, 새우첨가	KOR	117017	207,0	62,1	18,7				7,8	11,4	
볶음밥, 냉동, 햄첨가	KOR	117018	247,0	61,8	15,9				3,4	18,9	

2.4.2 Blood Glucose and carbohydrates

Blood glucose level is affected by different factors such as physical activity, stress, etc. Nutrition management is about what people eat food or drink, and it is also one of the factors which influence blood glucose levels. Blood glucose control can be improved if the people with diabetes understand how different nutrients affect their blood glucose levels (51).

Carbohydrates in foods is the main nutrient which affects postprandial blood glucose levels (52), (53), (54). Experience from studies shows that people can predict approximately how much blood glucose level will be raised when the people know how much carbohydrate meal contains. Glycaemic responses are differing by amount of carbohydrates (55). The total amount of carbohydrate intake can be a reliable predictor of postprandial blood glucose (56), (57).

Carbohydrates are nutrients which have the biggest impact on blood glucose level in the short term. Fat has low impact on blood glucose level in short term. Protein does not have a big role in controlling blood glucose level in short term, because it takes several hours to be degraded into glucose.

2.4.3 Why do we need carbohydrate counting?

The biggest issue in managing diabetes is due to not enough insulin or insulin which is not used properly, raising blood glucose level and causing complications. Therefore it is important to think about the amount of carbohydrate intake which can be transferred to

glucose immediately after eating in diabetes diet management. Knowing the amount of carbohydrates intake, can enable us to predict how much the blood glucose levels will be raised. It then helps us to prevent a rapid rise of blood glucose level and to prepare measures for that.

For the people with Type 1 diabetes who use insulin, carbohydrate counting is essential to know how much insulin is needed. The person needs to count carbohydrate from the food which will be eaten. Then the person needs to balance the amount of carbohydrate from food together with the amount of insulin in the dose or additional insulin dose by insulin pump (Post-meal insulin or secreted insulin into blood to manage the absorbed carbohydrate when people who have normal pancreas eat carbohydrate). By injecting the correct amount of insulin which can manage the absorbed carbohydrate, the person can do what the healthy pancreas does. In order to balance with carbohydrate intake, the required amount of insulin can be decided by ratio of carbohydrate and insulin.

For the people with Type 2 diabetes, calculating carbohydrate and recording it is more important. The biggest impact on their blood glucose level is the carbohydrate is contained in the food items which they have eaten. Once people start to count carbohydrate, they get to know which foods make their blood glucose reach danger levels sooner. This then allows them to keep their blood glucose level within the acceptable range by avoiding the foods which increase their blood glucose level. The opposite is also true, people getting to know which foods don't have a bad impact on their blood glucose level, and can therefore eat the food properly without unnecessary concern.

As a meal planning approach, carbohydrate counting has been used for people with diabetes who focus on the total carbohydrate of the food which they have eaten at meal and snack (58). Since the 1920s, the concept of carbohydrate counting has been used, and as 1 of 4 meal planning approaches in the Diabetes Control and Complications Trial, carbohydrate counting has got renewed attention (59).

Carbohydrate counting tools are increasingly used due to the benefits of intensive therapy and has been demonstrated in people with Type 1 diabetes (60), (61), (62). Sandra et al. (58) showed how carbohydrate counting can be used by people with Type 2 diabetes. Johnson (51) argued that carbohydrate counting is also an effective medical nutrition therapy option for adults with Type 2 diabetes because it can also lead to improved diabetes control and weight loss in adults with Type 2 diabetes. Carbohydrate counting can provide people with Type 2 diabetes enlarged flexibility in food choices and a means for better blood glycaemic control (51), (58).

Carbohydrate counting is a way to learn about how different food and the amount of carbohydrates affect diabetics' blood glucose levels. It is also a way of learning, maintaining a healthy diet and having a balanced diet for people with diabetes. Metabolic control can be improved by careful attention to carbohydrate amount and distribution (58).

2.5 Summary

This chapter provides the basic knowledge about diabetes such as types, symptoms, prevalence and cost in the beginning. Patient's self-management and self-efficacy is then introduced with the importance of self-management in nutrition for people with diabetes. Next, this chapter shows some literatures describing mobile terminal-based support tools for management of diabetes focused on diet as the state-of-the-art. Lastly the concept of 'Carbohydrate counting' was introduced. The possibility to manage nutrition with 'Carbohydrate counting' and the further possibility to improve glycaemic control is then described.

Chapter 3

Materials and method

3.1 Research Paradigm

The engineering approach described by Denning (12), is used in this thesis. Following aspects are used to describe my thesis topic in this paper.

(1) State requirements;
(2) State specifications;
(3) Design the system;
(4) Implementation;
(5) Test the system;

It is possible that more requirements are revealed later or the original requirements need to be adjusted. Therefore the above process is iterative.

3.2 Materials

To develop application, below development tools were used in this thesis project:

Device: MOTO GLAM XT800w

IDE: Google App Inventor

Languages: Visual blocks programming language

SDK/OS: Android 2.1

Major Libraries: Open Blocks Java library

3.3 App Inventor[2]

Google App Inventor is a tool which enables people to make application for Android phone. Graphical interface in Google App Inventor is similar to Scratch and StarLogo TNG user interface. By just drag-and-drop the visual objects in Google App Inventor, the users can make an application on the Android system.

Motto of Google App Inventor is programming can be a vehicle for engaging powerful ideas through active learning. And it started with the work of Seymour Papert and the MIT Logo Group in the 1960s as part of a continuing movement in computers and education.

Visual blocks programming languages is created by the block editor using the Open Blocks Java library. Open Blocks visual programming is originated from master's thesis research by Ricarose Roque and distributed by the Massachusetts Institute of Technology's Scheller Teacher Education Program (STEP). The StarLogo TNG, a project of the Klopfer's STEP, and Scratch, a project of the MIT Media Laboratory's Lifelong Kindergarten Group are closely related to Open Blocks visual programming. The Kawa language framework and Kawa's dialect of scheme programing are used by compiler to translate the visual blocks language for implementing on Android.

3.4 Open Blocks[3]

The Scratch programming language is developed by the Massachusetts Institute of Technology (MIT) Media Laboratory's Lifelong Kindergarten Group.

OpenBlocks is an open-source Java library to create blocks-based programming UIs. There are two packages in OpenBlocks. They are codeblocks and alcodeblocks. Codeblocks has responsibility for most of functionality as basic underlying library. Slcodeblocks is code that is generated by project, StarLogo TNG. To entirely implement StarLogo TNG's UI, codeblocks library is used and extended by StarLogo TNG.

3.5. Data Collection & Experiment Methods

Data which can determine success or failure of this project were collected by tests in Norway and South Korea.

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[2] http://en.wikipedia.org/wiki/Google_App_Inventor
http://appinventor.googlelabs.com/about/moreinfo/

[3] http://education.mit.edu/openblocks

My test includes questionnaires, a presentation about 'Carb counting', a presentation about the application developed, usability test and verbal interviews to ask how they think about 'carb counting' and the application. Test with Norwegian subjects were held in Harstad Hospital on the 23rd and 24th of May. Test with Korean subjects were held in Seoul St. Mary's Hospital from 30th of May to 3rd of June. The participants in Norway were from focus group which have used 'Few touch application (10)' for more than 1 year. However participants in South Korea were recruited among outpatients helped by an announcement in the bulletin in the department of Endocrinology and Metabolism. A total of 27 participants engaged in the test and the participant's age range was 40 to 80 years old.

3.5.1 Test in Norway

Tests with Norwegian subjects were held together with the final meeting in Harstad for the project "Motivation to mobile". Questionnaire and presentation about 'Carb counting' was shown at the focus group meeting on the 23rd of May, and participants were recruited after the presentation. Presentation about application, usability test and verbal questions about the system were conducted in individual interviews on the 23rd of May and 24th of May. All the process of the test in Norway was conducted in Harstad hospital.

Total 7 people (1 female and 6 male) were recruited for the individual interviews. There were 9 people at the focus group meeting but one left before the presentation about 'carb counting' due to work schedule. 6 people among 8 decided to take part in individual interviews, and one more participant were recruited through a participant's phone call by providing information about the individual meeting.

3.5.2 Test in South Korea

January in 2011, a meeting was held in Seoul St. Mary hospital to discuss about experiment in South Korea. The topic was introduced with introduction to NST, TTL and the researcher.

To recruit participants, an announcement about the test hanged on the bulletin board in the Department of Endocrinology and Metabolism in Seoul St. Mary's hospital from the morning on the 30th of May to the afternoon on the 3rd of June. Questionnaire and presentation about 'Carb counting', presentation about application, usability test and verbal questions about the system were conducted in individual interviews from the 30th of May and 3rd of June. All the process of the test in South Korea was conducted in Seoul St. Mary's hospital.

Total 21 people (10 female and 11 male) were recruited for the individual interviews. One participant's age was outside of the range. Therefore here I analyze the test result from the only 20 participants.

3.5.3 Questionnaire

The questionnaire consisted of three parts. There are questions about general personal information, blood glucose controlling and carbohydrate counting. Questions about basic personal information such as age, gender and number of year first diagnosed as diabetic and whether they use insulin or tablets were asked in the general personal information part. The second part consisted of questions regarding the control of blood glucose. How the subjects manage their blood glucose level and whether it is difficult for them and the reason were investigated. In the last part, carbohydrate counting part, subjects' knowledge about carbohydrate and their awareness of its importance were asked. The questionnaires are included in the Appendix.

3.5.4 Presentation

Concept of 'Carbohydrate counting' was introduced after the questionnaire was done. A power point file was used for this.

'Smart Carb' application was introduced after the presentation of 'Carbohydrate counting'. Another power point file was used for this presentation. Real food items were used in this presentation when they practice 'Smart Carb' application with an example of typical diet. The reason for this is to let the participants practice in the same environment like real life. The detailed food items that were used are introduced in Chapter 7.

3.5.5 Usability test

System Usability Scale (SUS) by Digital Equipment Corporation in 1986 (63) was used in this test. SUS form is available to download from below website. http://www.usabilitynet.org/trump/documents/Suschapt.doc

Degree about below questions was asked in the test.

- How often does the participant want to use 'Smart Carb'?
- How complex is 'Smart Carb'?
- How easy is 'Smart Carb' to use?
- Necessity of technical support to use 'Smart Carb'
- Degree of integration of different functions in the system
- Degree of inconsistency in the system
- How quick can people learn to use the system?
- How much cumbersome is the system to use?
- How much confident is the user using the system?
- Necessity of learning, before start to using the system

3.5.6. Verbal questions about the system

Some questions were asked at individual interviews. Mostly the reasons why they remarked on the SUS sheet were asked. In addition some questions about carbohydrate counting and 'Smart Carb' application were asked as well.

It includes:

- How do they think about 'Carbohydrate counting'?
- How do they think about 'Carbohydrate counting' with 'Smart Carb' application?
- Whether 'Smart Carb' application is helpful for participants to learn how different food influences their blood glucose levels
- Which parts in the application is the most useful?

3.6 Evaluation Methods

To get feedback on how the system appeals, usability test were conducted and some verbal questions were asked. Questions about the functionality and what should be improved, etc. were included in the sections.

How to use the system was presented by a researcher first. Then the participants got a chance to try the system. Usability test were conducted after that. Finally some verbal questions about the system were asked. Analyses of the results regarding usability test and answers about the verbal questions were done by comparative method and qualitative method.

3.7 Critique of the Methods Used

Comparative method was used to evaluate and analyse the data from the tests. It is a good method to compare between groups. Here, the Norwegian and Korean groups were compared. However the characteristic of the group was not same. It took a lot of time to establish contact with Korean participants. It includes set up contact with a doctor in the hospital, planning and validation of interventions with patients together with the health personnel, applying for permission to ethical committee to involve patients for the test. Therefore it did not leave enough time to establish contact with new Norwegian participations who had not have experience with 'Few touch application' like Korean group.

To recruit Korea participants, test announcements hung on the bulletin board in the hospital from first day for the test. Only 2 people among 20 people were recruited though the announcement. The others were recruited by asking outpatients. Most of the outpatients were in hurry; therefore it was not easy to recruit participants. There was one person who

called me and asked possibility to participate the test after the test was terminated. If the test announced 1 or 2 weeks ahead, it could be easier to recruit participants who are more active and actually interested in having the test.

During the tests, not all the participants tried the system themselves. Many of Korean participants were afraid to try the application because they did not have any experience with smart phone. Some of Norwegian participants were not familiar to using Android phone, did not dare to try 'Smart Carb' application. Therefore SUS (System Usability Scale) could not be conducted properly. Some participants who tried the application said the time of use was not enough to answer the usability test and verbal questions about the system. If longer time of use allowed, more accurate answers would be obtained.

3.8 Summary

The following methods were used for this thesis project.

- System design (Engineering approach)
- Data collection (Questionnaires)
- Experimentation (Usability test and Verbal questions)
- Evaluation or Data analysis (Comparative method and Qualitative method)

How this thesis follows an engineering approach to develop a system, is described in this chapter. Developing material such as device, IDE, language, OS, etc. are also introduced.

This chapter then goes to introduce 'App Inventor' and 'Open blocks' as materials used in development process. Data collection, experimentation and evaluation are also explained. Lastly, the critique of used methods is written in this chapter.

Chapter 4

Requirements and specification

The Volere Requirements Specification Template was used in this chapter. Here are some assumptions for making prototypes.

I. All the data is stored and available on the terminal (mobile phone)'s memory and it is not transferred to external storage.

II. Only the owner (one person) operates the terminal to protect patient sensitive information.

III. An integrated set of functions of mobile phone is available on this phone. Such as receiving and sending SMS.

4.1 Source of requirement

Previous work which is done by "Lifestyle" research group at NST provided the main source of requirements which are well explained (6). Diabetes patients were recruited for this previous research and the group has been working on a diabetes self-help tool. From the participants' feedbacks, it was found that they wanted to have more advanced tool for nutrition management. It was the big research reason and also requirement for this thesis project.

More detailed information about the food they eat, and a function which enables them to know the influence on their blood glucose levels by changing their dietary habits, are the main points for improvement.

A paper prototype was made first. Then a excel prototype was built based on the idea.

Other requirements were taken from advice given by a nutritionist in Norway and a nutritionist in South Korea. A meeting with a Norwegian nutritionist was held in Oslo to get feedback and opinion from nutritionist's point of view. At the meeting, the excel prototype was presented and the points for improvement were discussed.

To improve the excel prototypes, some more requirements were taken from advice given by one of diabetes patients who have engaged to the “Lifestyle” research project at NST.

Regarding how to categorize the food items, e-mail advices from the nutritionists in Norway and South Korea were taken.

4.2 Functional Requirements

To get the functional requirements for the application, I tried to figure out the problems the patients faced in. Following scenarios describe people with diabetes who have difficulties in nutrition management. This process helped me to figure out what kind of functions should be included in the application.

4.2.1 Scenarios

- **The people have shorter period diagnosed with diabetes, tend to have the more difficulties in nutrition management** (7)**.**

Mr. Will was diagnosed with diabetes a month ago and he started to measure his blood glucose levels every day after meals. He wants to know how the food he eats affects his blood glucose level and wishes to change dietary habits to manage his blood glucose well.

- **Too much nutrition information can overwhelmed some patients with diabetes** (51)**.**

Mr. Sam has been Type 2 diabetics for 5 years. However nutrition management has always been the most difficult task for him. He checks nutrition information of food items but it is difficult for him to analyse nutrition facts. He thinks there is too much information on the nutrition label and that confuses him when he selects food items. He wishes for simple information that allows him to check the actual factors that influence his blood glucose levels.

- **People with diabetes want to motivate themselves to follow their meal plan** (7)**.**

Ms. Rose has been Type 2 diabetics for 7 years. She has taken courses on how to manage nutrition to control her blood glucose levels several times since she diagnosed. She knows what kind of food items she should avoid to keep her better blood glucose levels. However due to her busy lifestyle at work and also at home, it is difficult for her keep checking her blood glucose levels after meals. She easily forgets to measure it. She thinks it will be helpful for her to have something that can notify her to measure her blood glucose levels after meals, so that she can make sure if she is managing well with her dietary to improve her glycaemic control.

- **‘Includes the right portions of foods’, one of the most dissatisfied factors in diabetes dietary lifestyle** (7)

Mr. Tom has been Type 2 diabetic for 10 years. He is a policeman and has random work shift. When he has enough time for a meal, he has a bigger portion than the other days when he does not have enough time due to his work shift. He knows how it is important to manage what he eats, to keep his blood glucose levels within a therapeutic range. When he plans about what to eat for a meal, he always cares about the food items and their influence on his blood glucose level. However, he thinks his nutrition management is poor because sometimes his blood glucose levels go up unexpectedly. He guesses that maybe it is because the amount of food he eats varies. He wants to know the relationship between amount of food and his blood glucose levels.

From the above scenarios, the points that four different people wish, can be summarized like below.

They want to have:

- A tool which shows the different food items’ influence on the users’ blood glucose levels so that they can be stimulated to change their food habits
- A tool provides simple nutrition information based nutrient which mainly affects blood glucose levels
- A tool notifies people with diabetes to measure blood glucose level
- A tool displays nutrition information depending on amount of the food items

4.2.2 Required behaviour

To see how food affects blood glucose level, four behaviours are required.

- Measuring blood glucose level before meal
- Recording meal
- Measuring blood glucose levels after meal
- Checking the relationship between food and blood glucose level

4.2.3 Functional requirements

Based on the above 4 points and 4 required behaviours, functions of prototype were decided. Event list and use case diagrams are following later in this section to draw possible interactions in this system.

A. Time

Time is important to consider in this system. Because the user needs to check the difference of their blood glucose levels before and after meal. Therefore the time BG measured should be recoded to show the time difference.

B. Carbohydrate amount

To provide simple nutrition information, carbohydrate was selected because it is the main nutrient which influences blood glucose level largely. So the amount of carbohydrates contained should be displayed in this system to help users check the different amount of carbohydrates in different food and help themselves to make right decision on food intake. Also the total carbohydrate of several food items which are chosen should be calculated and shown.

C. Blood glucose level

Blood glucose level should be registered, and the difference of blood glucose level before and after meal should be calculated and showed to see the food item's influence on it.

D. Notification

Notification to let the user know the time to measure their blood glucose level after the meal should be considered importantly. Due to the people's busy life style in modern society, it is easy to forget a task which we should do therefore many different means are using such as sticky note, dairy, etc., to help them remember the task. In this system, sending and receiving SMS are used for notification.

E. Stopwatch

Stopwatch is also one of important requirements to support personalization for this system. Because the schedules of the users and the time when they wish to measure their blood glucose level after meal is various. By using the stopwatch function, users can set the time interval to available time for themselves.

4.2.4 Event Listing and Use Case

Event list was made to count the functional requirements systematically. The below event list (Table 6) includes possible inputs and outputs, and also all the event which can occur in this system.

Table 5. Event list

	Event name	Input/output	Summary
1	Open application	Time and BG level input screen (output)	Open application, then the screen show time, date and BG level input text box
2	Save BG level before meal	BG level (in) Food category (out)	Measure and save BG level before meal
3	Select food category	Food category (in) Food list (out)	Click food category, then it shows food list of the selected food category
4	Select food item	Food item (in) Carbohydrate info (out)	Click food item, then it show contained carbohydrate amount of selected food item per 100 gram or per portion size
5	Save food weight	Food weight (in) Carbohydrate amount (out)	Weigh food item and save the weight, then it shows carbohydrate amount of the weight of the food item
6	Save as meal	Carbohydrate amount (in) Stopwatch (out)	Save food item as meal, then it shows stopwatch
7	Add more food item	Carbohydrate amount (in) food category (out)	Click 'Add more food' button, then it shows food categories again
8	Set stopwatch	Time interval (in) Time countdown (out)	Set time interval and click start button, then time will be countdown behind the application
9	Close application screen	System work behind	Click 'Home' button in the phone, then the system will work behind
10	Get notification	Sending SMS (in) Receiving SMS (out)	Notification is arrived by sending and receiving SMS to the phone itself
11	Open application screen	Show application screen	By clicking the application again, the application screen is shown
12	Next	BG level input screen (out)	BG level input screen after meal is displayed after clicking 'Next' button
13	Save BG level after meal	BG level (in) BG levels' difference + measured times (out)	Measure BG level after meal and save it, then it shows difference of BG levels with detailed time information.
14	Learn from food intake	Selected food list, gram or portion size and carbohydrate amount (out)	Click 'Learn from food intake', then it shows all the food items selected with food name, weight or portion size and carbohydrate amount
15	Close the application	Inactivate application	Close the application

A UML use case diagram (Figure 14) was built by using the event list above to outline the scope of the prototype. Interactions between the user and the system and the boundaries of the prototype are drawn in below use diagram.

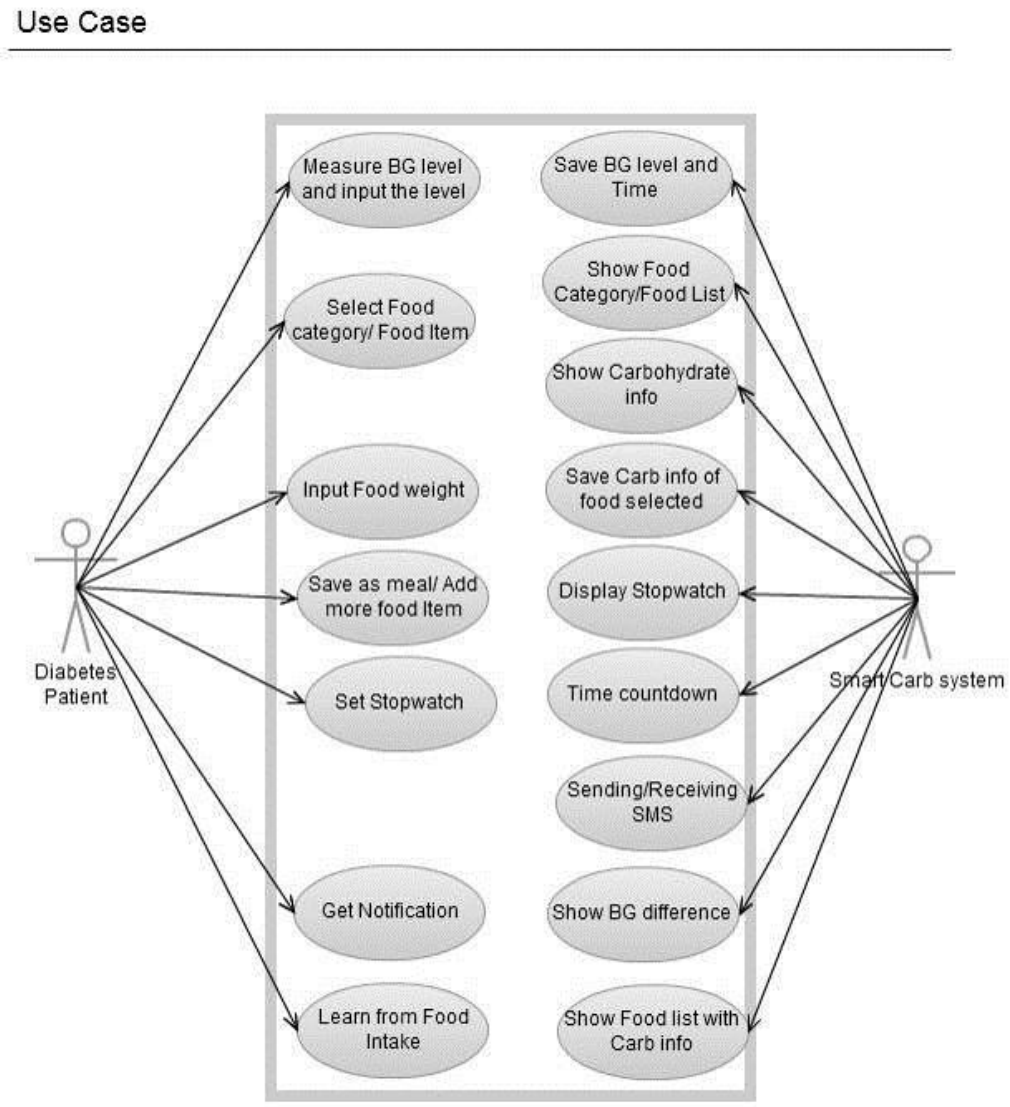

Figure 14. UML use case diagram for 'Smart Carb' application

Use Case 1: Input BG level before/after meal (Actor: Diabetes Patient)
1. Measure blood glucose level before/after meal
2. Input the level into the textbox
3. Click the save button

Use Case 2: Save BG level and Time (Actor: Smart Carb system)
1. Save the time of recoding BG level
2. Save the BG level

Use Case 3: Show Food Category/Food List (Actor: Smart Carb system)
1. Show the food categories/the food items of selected food category

Use Case 4: Select Food Category/Food Item (Actor: Diabetes Patient)
1. Think food category/food item
2. Find the food category/food item
3. Click the found category/food item

Use Case 5: Show Carbohydrate info (Actor: Smart Carb system)
1. Read the use's input
2. Show the carbohydrate information (Carb amount per 100g) of the selected food item

Use Case 6: Input Food weight (Actor: Diabetes Patient)
1. Weigh the food item wish to eat
2. Input the weight into the textbox
3. Click 'Save' button

Use Case 7: Save Carb info of food selected (Actor: Smart Carb system)
1. Save the carbohydrate amount of the selected food item
2. Save weight of the selected food item
3. Save the name of the selected food item

Use Case 8: Save as meal/Add more food Item (Actor: Diabetes Patient)
1. Check the carbohydrate amount of the registered weight of the food item
2. Think if there is more food item wish to eat
3. Click 'Save as a meal' button/'Add more food' button

Use Case 9: Display Stopwatch (Actor: Smart Carb system)
1. Display + and – buttons of hour, minute and second to set up countdown watch

Use Case 10: Set Stopwatch (Actor: Diabetes Patient)
1. Think after how many hours want to measure blood glucose level
2. Adjust the time interval
3. Click 'Start' button

Use Case 11: Time countdown (Actor: Smart Carb system)
1. The time set up is counting down

Use Case 12: Sending/Receiving SMS (Actor: Smart Carb system)
1. The countdown watch is stopped
2. Send SMS to the phone itself that it's time to measure blood glucose level
3. Receive SMS from the phone itself that it's time to measure blood glucose level

Use Case 13: Get Notification (Actor: Diabetes Patient)
1. Get SMS notification after the time interval

2. Open, read and close the SMS
3. Reopen the application

Use Case 14: Show BG difference (Actor: Smart Carb system)
1. Display the date
2. Show the difference of blood glucose levels before and after meal
3. Show the recoded blood glucose levels before and after meal
4. Show the measured times of blood glucose levels

Use Case 15: Learn from Food Intake (Actor: Diabetes Patient)
1. Click 'Learn from food intake' button

Use Case 16: Show Food list with Carb info (Actor: Smart Carb system)
1. Show the names of the recoded food items
2. Show the weights of the recoded food items
3. Show the contained carbohydrate amount of each food item recorded

4.2.5 Non-functional requirements

Usability

Lack of usability disturbs users to use the system. For this reason, many disease management applications were not used in a long term based. An example of the failure is shown by Keshavjee et al. (64). Even though the system has lots of functions that give the users benefit, if the users do not want to use the system, it is useless. The system in this thesis should improve the usability of nutrition management module in a previous developed self-help tool for people with diabetes. Encouraging people with diabetes to think about the relationship between food items they have and their blood glucose levels, then making them help themselves in food selecting is the main requirement of this thesis project.

Security

Only one person possesses the mobile phone all the time. This is assumption of this thesis project. Because health-related information is confidential so it should be treated very carefully. Usually a mobile phone is regarded as a personal belonging and the applications and messages in the phone are only possessed by the owner.

Legal

This thesis project includes test with people with Type 2 diabetes in Norway and in South Korea. Therefore approvals from ethical committees in both hospitals were needed before the procedure was on-going. I applied the approval to the ethical committee in the Korean hospital by following the rules and submitting all the necessary documents. One of my

supervisors helped me to get the approval for the test with Norwegian subjects. After all the approvals were arrived, I was able to conduct the follow-up procedures.

4.3 Summary

Volere template based requirement analysis and specification is illustrated in this chapter. The majority of requirements were obtained from the previous research at NST. Advice from nutritionists and a diabetes patient were also taken as sources of requirement. To explain the functional requirements better, this chapter presents several scenarios.

Measuring blood glucose levels before and after meals, recording meal contents and checking the relationship between food and blood glucose level were decided as required behaviours. Based on these required behaviours, functional requirements were concluded. Later, this chapter describes event list and use cases. Lastly, this chapter presents non-functional requirements.

Chapter 5

Design

5.1 Design Goals and considerations

People with diabetes need to have good understanding of diet regimen for their successful diet management. Therefore the following parts should be well reflected to design a tool that supports their diet management.

- Recording food intake in an easy way but accurate manner
- Educational materials with database of food items
- Feedback based on personal data in an easily interpretable way

To achieve the above three design goals, the system was considered to include three parts like below.

- Searching and recoding

How to find food items and how to record the food intake is very crucial to design the application. Therefore different search methods and different recoding methods exist. At the beginning text search was used as food search method for some prototypes. However to support ease of use and shorten the time of search, search method for this system was changed to category search. To support the accuracy of recoding food intake, typing the weight of food items manually was adopted.

- Database and calculating

For educational purpose, this system should show the amount of carbohydrate in food items and also the total amount of carbohydrate in all the selected food items the user had or will have. To display the amount of carbohydrate in food items, the system must have database of food items with carbohydrate information. To check the amount of carbohydrate based on the weight of food item and the total amount of carbohydrate intake from several food items, the system should have calculation function. For those people who use insulin, especially for the people with Type 1 diabetes, calculating the amount of post meal insulin can be

beneficial.

- Registration

To give feedbacks on how the food items influenced the users' blood glucose levels based on personal data, the system should have a registration part included to save their blood glucose levels before and after meal. Saving insulin dose can be included in this part for those people who use insulin, especially for the people with Type 1 diabetes to check how much insulin is needed for them after a meal.

5.2 Design variables

To enhance the usability of the application, the following variables were considered during designing process.

5.2.1 Text

Text that will be displayed in the application was simplified. Mobile phone screen has limited space. Therefore it is important to consider how to use the limited space efficiently when we design mobile phone based application. Firtman (65) argued that we need to try to reduce the amount of text for mobile web design.

5.2.2 Font

Size

Much bigger font sized was adopted for the amount of carbohydrate and the difference of blood glucose level in the application's screens. The reason for this is to enable the users to see the most information easier than other information.

Colour

The target users for 'Smart Carb' application are people with diabetes. Retinal damage is one of the serious long-term complications of diabetes. Therefore it was avoided to use Red and Green colours at the same screen.

Different text colours were used to help the users to distinguish the information provided. Black colour was used for the carbohydrate amount of food items per 100g. Blue colour was used for the carbohydrate amount of food items based on the weight or portion size. Pink colour was used to display the total carbohydrate amount of several food items.

Red colour was used to show the difference of measured blood glucose levels while Black

colour was used for the each measured blood glucose level before and after meal.

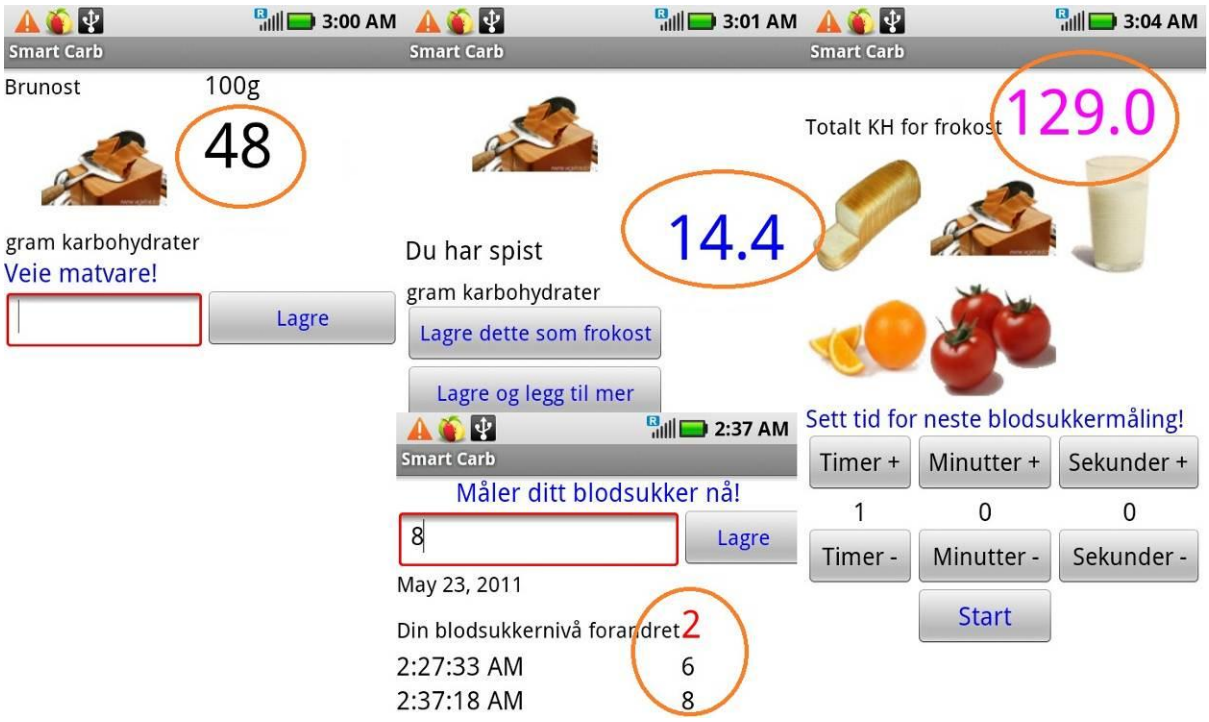

Figure 15. Different font sizes in screens

5.2.3 Picture

Visualization is also one of the most important variables in designing a mobile application. Therefore real pictures of food items were included to enhance the visualization of the application.

Pictures are displayed when they check the contained carbohydrate amount of each item. This provides the user a strong impact to help them remember the contained carbohydrate amount of the selected food items.

By showing the pictures of all the selected food items when the users check the total carbohydrate amount, the users can see the composition of the diet visually. It enables the users to think about their entire diet and food items. The pictures are displayed again when they reopen the application to input their blood glucose levels after meal. This helps the user to remember what they had.

Tidwell (66) argued that photographs are encouraged to be used in designing interface because they make the user react positively by appealing to the deepest human instincts.

5.3. Prototyping

5.3.1 Paper prototype

At the beginning of this research, the target group for this application was people with Type 1 diabetes. Therefore insulin dosage was used as one of input parameter in the paper prototype (Figure 16). Carbohydrate and insulin ratio and required post meal insulin were regarded as output parameters in this paper prototype.

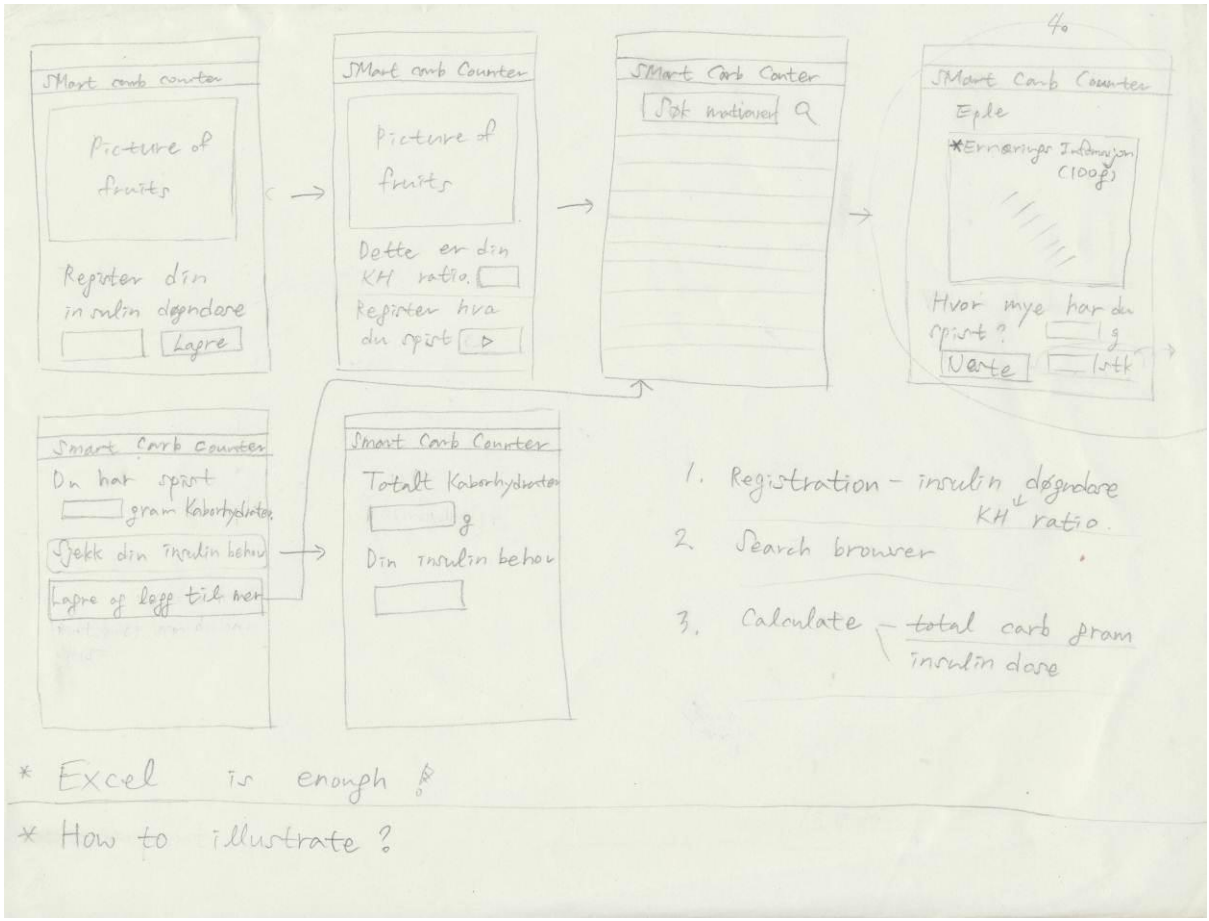

Figure 16. Paper prototype

The user can register insulin dosage and then carbohydrate ratio is shown by the system. After that the user can browse the food item by typing the name of food item, carbohydrate information of the food is shown per 100 gram. The user weighs the food item with scale and input the weight. The carbohydrate amount based on the weight is shown and asked if the user want to register more food items or not. If the user selects the button to add more food item, the system goes back to the screen finding food. If the user clicks the button to check insulin requirement, the screen shows the total carbohydrate amount and the required amount of post-meal insulin.

5.3.2 Excel prototype

Because most of the function in this research is based on calculation, excel was recommend as a tool for making rapid prototypes. The first version of excel prototype is presented below (Figure 17).

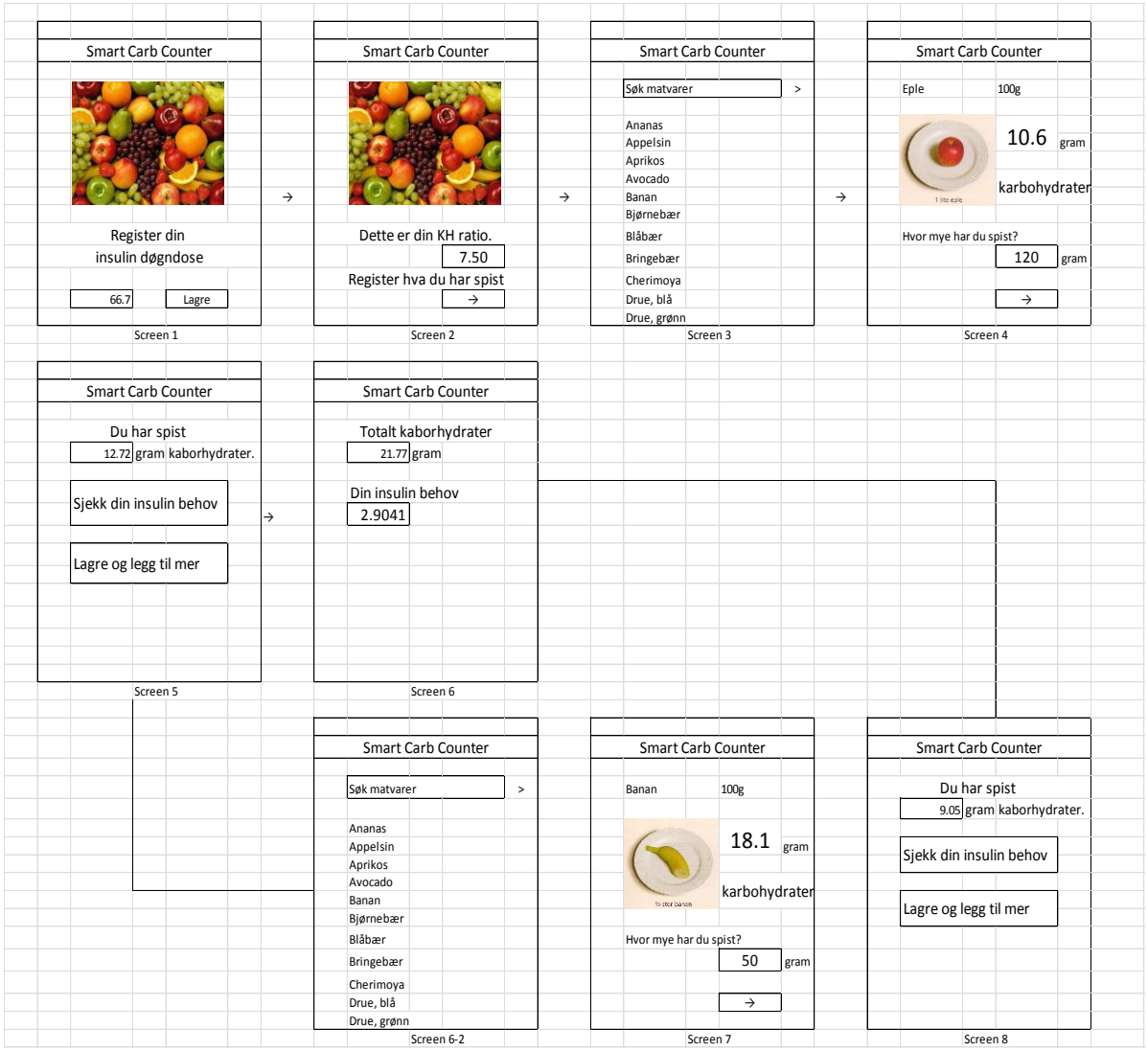

Figure 17. First version of excel prototype (Text is in Norwegian)

5.3.3 Meeting with a nutritionist

To get feedback and opinion about the excel prototype from nutritionist's point of view, a meeting was held in Aker university hospital in Oslo in April. Requirements and points to improve were discussed at the meeting.

The conclusions from the meeting were:

- Many diabetics suffer from poor nutrition management.
- The estimation of carbohydrate amount is one of the most difficult challenges for diabetics.
- The need to have an application which can be used to estimate amount of carbohydrate and makes people think its influence on blood glucose level.
- Interest about carbohydrate counting is increasing among people with Type 2 diabetes
- Possibility to develop a carbohydrate counting application for Type 2 diabetics with educational purpose.

5.3.4 Second version of the excel prototype

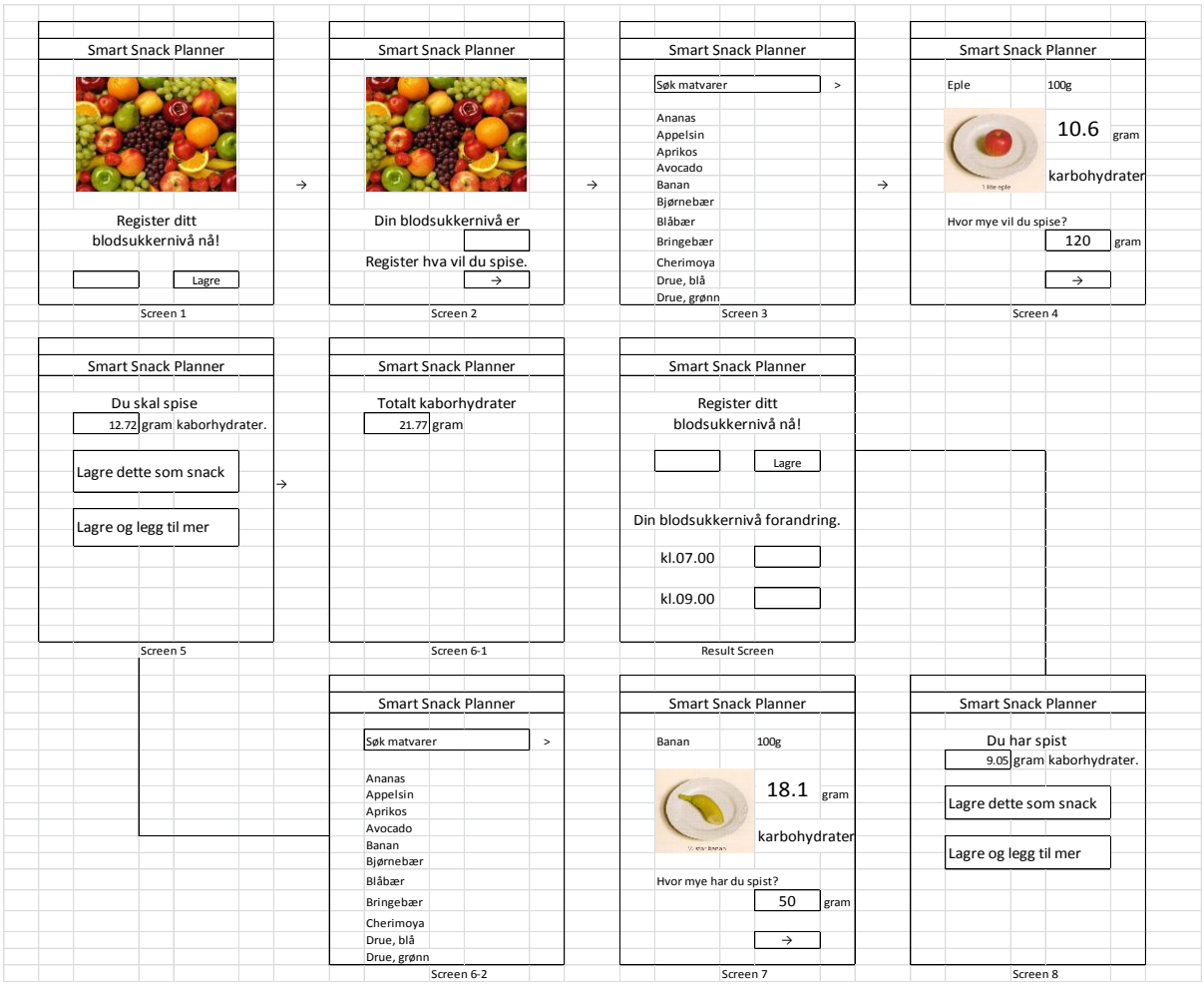

Figure 18. Second version of excel prototype

As the result of the meeting with nutritionist, the target user for this application was changed from Type 1 diabetics to Type 2 diabetics. Therefore the screen for insulin dosage input, the screens show carbohydrate ratio and required amount of post-meal insulin dosage were eliminated. Instead of those screens, screens for blood glucose level input before and after meal and a screen which shows blood glucose levels with the measured time information were added.

For the first excel prototype, registration of food was for the foods which are already eaten. But from this second version of excel prototype, food is registered before the meal. This is because the food item cannot be weighed after it was eaten. Therefore the tenses of sentences for food registration and carbohydrate information from the second version of excel prototype are all future tense, comparing to the sentences in first version of the excel prototype have all present perfect tense.

5.3.5 Feedbacks from a real living patient with diabetes

A real living patient with diabetes was involved in testing excel prototypes to get the feedback. The second, third and fourth version of the excel prototype were sent to the patient who have engaged to NST's "Lifestyle" research project earlier. The areas for improvement were discussed through mobile phone and Skype. Some requirements that he indicated were adopted.

5.3.6 Third version of the excel prototype

There are two different meal types in Norway. First one is bread meal type and it's usually cold meal. This includes breakfast, lunch and supper snack. Bread is the main food item for these meals and several of cold cut is served top of the slice of bread such as cheeses or precooked or cured meat, smoked fish, shrimp, jam, vegetable, etc. Second type of meal is dinner and it's usually warm meal. Potatoes, rice, pasta are the main source which includes carbohydrates. With this main sources, variety of food items can be served for this meal type.

Due to this different characteristic of meal types in Norway, it is decided that I would better focus on bread meal type in this thesis project.

Several changes were adopted for the third version of excel prototype like below.

- Date and time is displayed in the first screen for blood glucose level input.

- Drinks are liquid therefore it is followed below steps to measure the weight of drinks.
  1. Weigh an empty glass first with scale
  2. Input the weight into textbox in the screen of application
  3. Pour the drink into the glass
  4. Weigh the glass with drink with scale

5. Input the weight into textbox in the screen of application
6. The application calculates the weight of drink automatically
7. Use the weight of drink to calculate amount of carbohydrate contained

- After the user decides on food items to eat and register as meal, the screen shows the list of items with the names, weights and contained carbohydrate of the food items.

- Stopwatch function is integrated into the application to notify the user to measure blood glucose level after certain period of time from meal. After the time period, the user is encouraged to measure blood glucose level again.

However how to integrate stopwatch should be considered in more detail. It is researched in the next stage.

5.3.7 Fourth version of the excel prototype

Some points were improved in this stage as well. Below are the points which were improved from previous version.

- Text search can be more cumbersome than category search, because the user needs to type the spelling of the word of the food item. Moreover it takes more time to typing than just clicking. Therefore it is decided that I would better to go for category search method for this application. Several steps of categories can take more time so here only one category is adapted in this system. After the user click the category, the screen shows food list of the food category.

- Only 4 basic food categories are included in this excel prototype like bread, drinks, cheese and jam. To optimize the user's choice, more food categories will be discussed in next step.

- After the user weighs the food item and saves the weight, the picture of food item is shown again in the screen that displays the amount of carbohydrate in the weight of the food item. This is to enhance the system's visualization.

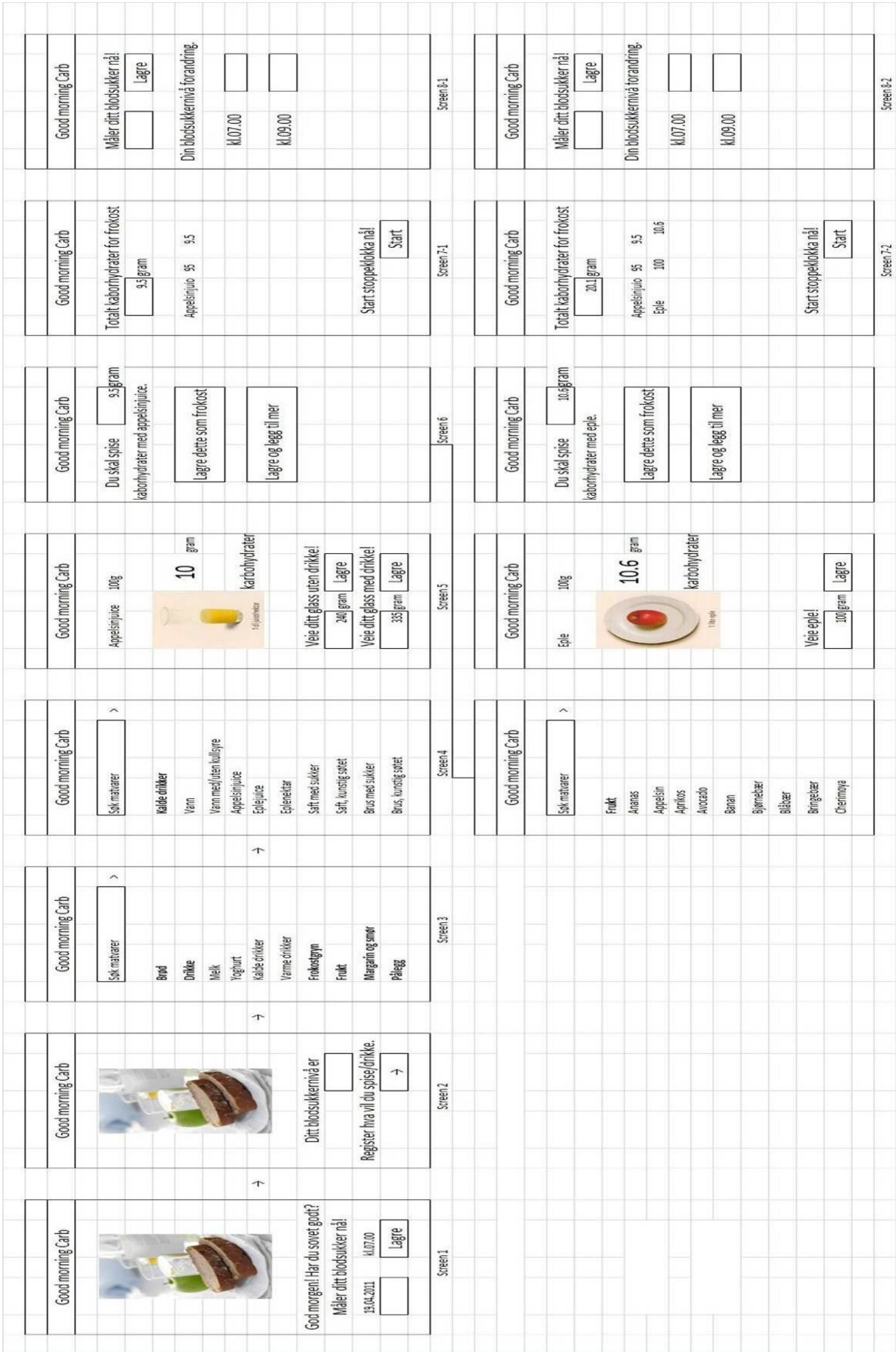

Figure 19. Third version of excel prototype

Figure 20. Fourth version of excel prototype

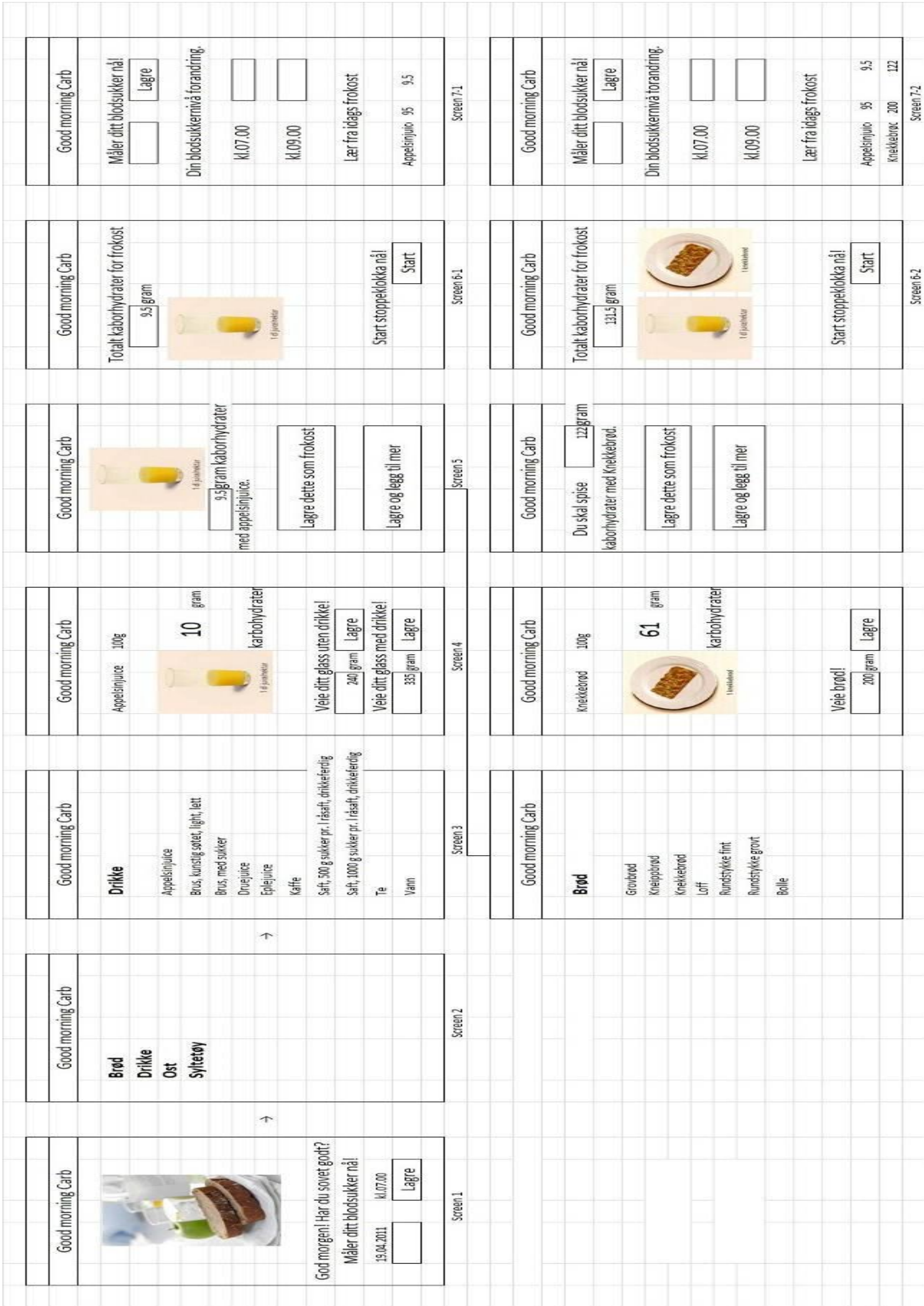

Figure 21. Fifth version of excel prototype

5.3.8 Fifth version of the excel prototype

Lastly more changes are adapted to improve the excel prototype. Here are the changes below.

- Food list with food name, food weight and amount of carbohydrate of each food item will be displayed after the users check the difference of their blood glucose levels and click the button 'Learn from today's breakfast'. The reason for this is to make the users to check how much carbohydrate is from each food item so that they can think about the influence of each food item on their blood glucose level.

- After the user registers food items as a meal, the screen shows pictures of each food items they selected, together with the total amount of carbohydrates from those food items. This is to make the users easier to check the food items which they will eat and also to enhance the visualization of this system.

5.4 Designing application

There are many different tools that can be used to develop an application. General impression about these tools has been accepted as different type of programing languages such as Java, C#, etc.

5.4.1 Google app inventor

App inventor is a tool to develop applications for Android mobile phones. Different from other programming languages such as java, c#, etc., the App inventor uses a web browser to develop applications. The developers' work can be stored in the Google App inventor servers and developers can access their projects through the web browser to continue their work without regard to place.

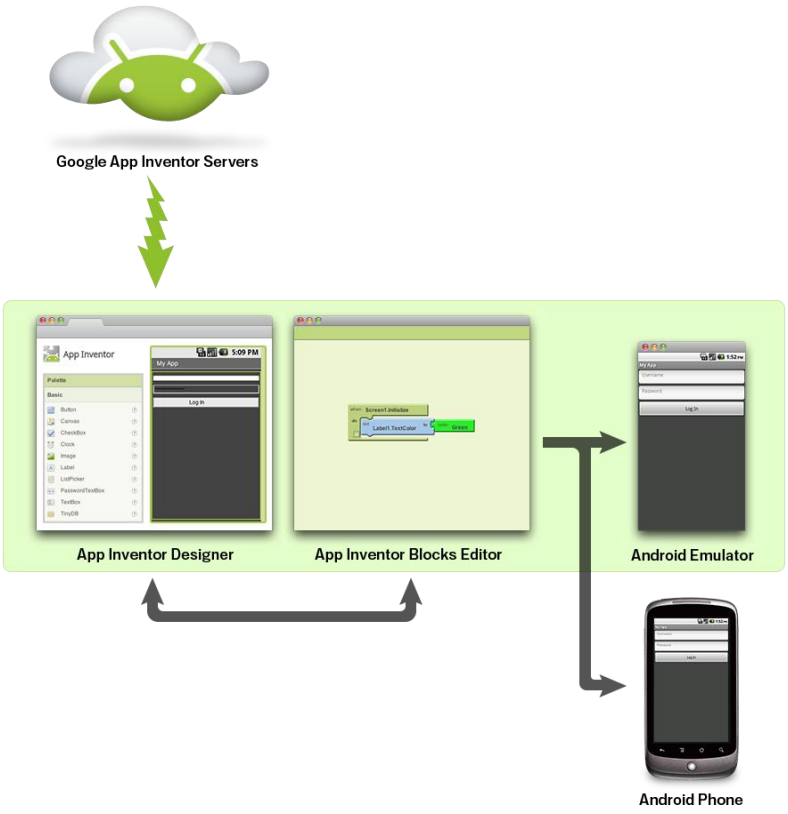

Figure 22. Structure of App inventor [4]

Developing includes two parts, design and coding part. Design part is done using the app inventor designer. Here the developer can design applications by selecting the design components on the web browser. Coding is done by programing visually. Block programing language is used in this part and the developers can code application by assembling blocks. Theses process is similar to puzzling or making blocks like Lego.

The applications developed by app inventor can be packaged through the web browser and installed into android phone or can be tested using the android emulator.

5.4.2 Simple model for testing

A simple application was developed firstly with 24 Norwegian food items to check the application's usability. The design was done by the app inventor designer like below.

[4] http://appinventor.googlelabs.com/learn/whatis/index.html

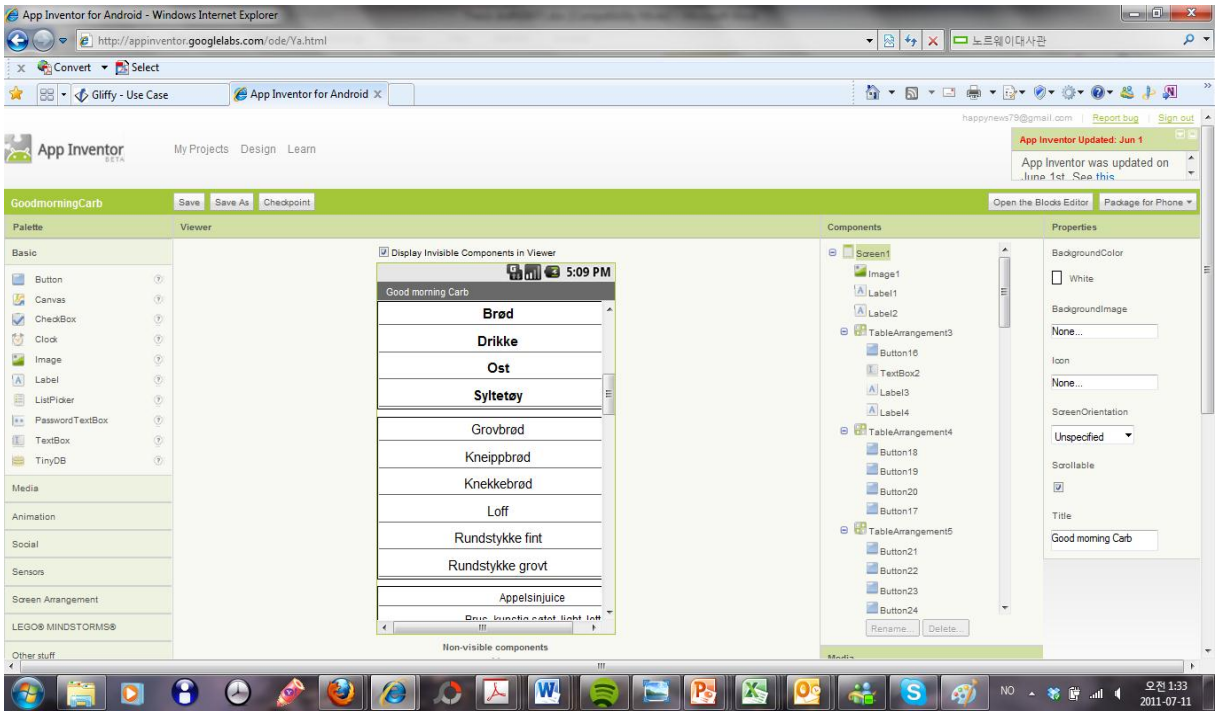

Figure 23. Designing first model by the app inventor designer

Table 8. Food items for first model (Text in Norwegian)

Bread	**Drinks**	**Cheese**	**Jam**
Grovbrød	Appelsinjuice	Brunost	Marmelade, appelsin
Kneippbrød	Brus, light, lett	Hvitost	Syltetøy med mindre sukker, lett
Knekkebrød	Brus, med sukker		Syltetøy, 1000 g sukker pr. kg bær
Loff	Druejuice		Syltetøy, 250 g sukker pr. kg bær
Rundstykke fint	Eplejuice		Syltetøy, 500 g sukker pr. kg bær
Rundstykke grovt	Kaffe		Syltetøy, 750 g sukker pr. kg bær
	Saft, 500 g sukker		
	Saft, 1000 g sukker		
	Te		
	Vann		

Food categories which represent normal Norwegian bread meal like bread, drinks, cheese and jam were used for this first model. All food items are in above table.

5.4.3 Categorizing and selecting food items

Different categorizing methods were used for Norwegian version and Korean version. Norwegian food items are categorized by food type. However Korean food items were categorized by the way to cook.

Different portion sizes were used also for Norwegian food and Korean food. Due to the

characteristic of food items, it is much easier for Norwegian food items to measure the weights with scale. However it's quite difficult for Korean food items to weigh because there are many liquid food items such as soup, stew, etc. Therefore as the reference unit for displaying the amount of carbohydrates, standard portion sizes were used for Korean version and 100 gram was used for Norwegian version.

A. Norwegian version

Bread, Meat and fish cold cuts, Cheese, Breakfast corn and porridge, Milk and Yogurt, Drinks, Sugar, honey and jam, Fruits, Vegetable

Above 9 categories were made for Norwegian version. By discussing with a Norwegian nutritionist, the categories were selected and organized. Oil like butter, margarine, mayonnaise was excluded in the categories because only small amount of oil is used to make food compare to other types of food items. However some food items such as salami, cooked ham and white cheese which do not have any carbohydrates were included into the categories as well. This application has educational purpose. Including these foods items would be useful for educational purpose. Therefore I decided to include these items.

"Matvaretabellen"[5] provided me the lists of food items that I can select. Like I mentioned earlier, the Norwegian version of 'Smart Carb' has limitation that it deals with the food items related to bread meal type. Based on this rule, 118 food items which represent each food categories were picked up from the item lists on the "Matvaretabellen" website. The information about the amount of contained carbohydrates of those selected food items were brought also from the same web site. Some items which have same or similar amount of carbohydrates were merged into one item. 'Egg(kokt, stekt, eggerøre, omelett), Melk(Alle typer) and Milkshake(jordbær/sjokolade)' are the exalples.

B. Korean version

Rice/Porridge, Soup/Stew, Kimchi/Pickles, Herbs/Seasoned food, Steamed food/Boiled food, Fried food/Grilled food, Fried food, Noodles/Dumplings, Drinks, Fruits/Vegetables, Rice cake/Bread

Above 11 categories were made for Korean version. How to categorize food item was discussed with a Korean nutritionist through e-mails.

Similar food items are served regardless the meal types such as breakfast, lunch and dinner in Korea. 150 food items which are the most common and popular in each category were selected. These items and the information about the amount of contained carbohydrates were brought from a smart phone application 'Calorie Codi[6]' which was developed by 'Korean food and drug administration'.

[5] http://matvareportalen.no

[6] https://market.android.com/details?id=com.mbus.cal&feature=search_result

Table 6. Food items for Norwegian version application

Brød	Kjøtt- og Fiskepålegg	Ost	Frokostkorn og grøt	Melk og Yogurt	Drikke	Sukker, honning og søtpålegg	Frukt	Grønnsaker
Baguett, fin	Egg(kokt, stekt, eggerøre, omelett)	Brunost	Corn flakes	Biola, syrnet melk, blåbær	Appelsinjuice	Honning	Ananas	Agurk, rå
Boller	Kaviar, lodderogn	Cottage cheese	Frokostkorn, sjokoladesmak	Syrnet melk, naturell(Biola, Cultura)	Brus, kunstig, lett	Marmelade, appelsin	Appelsin	Agurker, syltede
Grovbrød	Kaviar, torskerogn	Gomme	Grøt, havregrøt, med vann	Melk(Alle typer)	Brus, med sukker	Melkepålegg, sukret(Hapå)	Aprikos, tørket	Gulrot, rå
Hamburgerbrød, fint	Kaviarmix	Hvitost	Havre ristet, med frukt, olje(Crüsli)	Milkshake(jordbær/sjokolade)	Druejuice	Nøttepålegg(Nugatti)	Avocado	Isbergsalat
Kneippbrød	Krabbepinner	Kremost, naturell	Havregryn, lettkokte/store	Sjokolademelk, Litago	Eplejuice	Sjokoladepålegg, type Sjokade	Banan	Mais, hermetisk
Knekkebrød	Laks/Ørret , røkt	Mozzarella	Hvetebrikker(Weetabix)	Yoghurt, drikke, frukt	Kaffe	Sukker, brunt	Blåbær	Paprika, grønn
Loff	Leverpostei	Prim	Hveteflak ristet	Yoghurt, frukt	Saft, 500 g sukker	Sukker, farin, raffinade, melis	Bringebær	Paprika, gul
Lompe	Makrellfilet, i tomat		Hvetekli ristet(All-Bran plus)	Yoghurt, frukt, med müsli	Saft, 1000 g sukker	Syltetøy med mindre sukker, lett	Drue, blå	Paprika, rød
Pitabrød/Chapatti fint	Reker i lake		Kornblanding(4-korn)	Yoghurt, naturell	Te	Syltetøy, 1000 g sukker pr. kg	Drue, grønn	Rødbeter, syltede
Pumpernikkel/fullkornbrød	Rognleverpostei(Svolvær-/Lofotpostei)		Müsli med frukt, nøtter, søtet	Yoghurt, naturell, Biola	Vann	Syltetøy, 250 g sukker pr. kg	Eple	Sopp, rå
Pølsebrød, fint	Salami		Müsli med frukt			Syltetøy, 500 g sukker pr. kg	Fersken	Tomat cherry
Rundstykke fint	Servelat		Puffet havre, Havrenøtter			Syltetøy, 750 g sukker pr. kg	Grapefrukt	Tomat
Rundstykke grovt	Sinke, kokt		Puffet hvete med honning(Honnicorn)				Jordbær	
Tortilla fint	Sursild		Puffet ris				Kiwi	
Vafler	Tunfisk						Klementin	
							Mango	
							Melon, honnig	
							Melon, kantaloup	
							Melon, vann	
							Moreller	
							Nektarin	
							Plomme	
							Pære	

Table 7. Food items for Korean version

밥/죽류	국/찌개류	김치/절임류/젓갈	나물/무침류	찜/조림류	볶음/구이류	전/튀김류	면/만두류	음료	과일/채소	떡/빵
김밥	감자탕	깍두기	가지나물	갈치조림	감자볶음	김치전	떡만두국	두유	귤	단팥빵
김치볶음밥	김치국	깻잎짱아찌	고사리나물	감자조림	고등어구이	달걀말이	라면	사이다	단감	백설기
깨죽	김치찌개	나박김치	도토리묵무침	고등어조림	김구이	닭양념튀김	만두국	액상요구르트	단호박	소보로빵
닭죽	달걀국	배추김치	마늘쫑무침	달걀찜	낙지볶음	닭튀김	물냉면	오렌지쥬스	당근	송편(깨)
보리밥	동태찌개	열무김치	무나물	닭조림	닭갈비	부추전	비빔국수	우유	들깻잎	시루떡
볶음밥	된장국	오징어젓무침	무생채	돼지갈비찜	돼지고기볶음	오징어튀김	비빔냉면	차(녹차, 홍차)	딸기	약식
비빔밥	된장찌개	총각김치	미나리무침	두부조림	떡볶이	완자전	수제비	커피(원두)	바나나	인절미
쌀밥	미역국		미역초무침	메추리알장조림	멸치볶음	탕수육	자장면	커피믹스	배	절편
오징어덮밥	보신탕		배추겉절이	보쌈/돼지고기	버섯볶음		잔치국수		복숭아	크림빵
잡곡밥	부대찌개		상추겉절이	북어찜	불고기		짬뽕		사과	
전복죽	북어국		시금치나물	순대	삼겹살구이		쫄면		상추	
콩나물밥	삼계탕		오이생채	아구찜	소갈비구이		칼국수		수박	
팥죽	설렁탕		오징어무침	족발	어묵볶음		콩국수		오렌지	
호박죽	쇠고기국		콩나물무침	찐고구마,군고구마	오징어볶음		떡만두국		오이	
흰죽	순대국		호박나물	콩조림	오징어채볶음				자두	
	순두부찌개				잡채				참외	
	어묵국				장어양념구이				키위	
	육개장								토마토	
	추어탕								파프리카(녹)	
	콩나물국								파프리카(적)	
	토란국								포도	
	해물탕									

5.4.4 Smart Carb application

'Smart carb' application is a meal planning tool to help people with diabetes. It enables them to understand how their food choices affect their blood glucose levels. Carbohydrate counting gives an overview of carbohydrates in a variety of foods.

A. How to use the application

1. Input blood glucose level before meal
2. Choose food item (2 clicks: Category → Food item)
3. Input the weight of food item
4. Check amount of contained carbohydrates of the selected food item
5. Repeat from 2 to 4
6. Register food items as a meal
7. Check the total carbohydrate intake of the meal
8. Setting stopwatch
9. Send/Receive SMS after meal
10. Input the post-meal blood glucose level
11. Check the difference of blood glucose level
12. Check list of food items eaten (food name, weight and contained carbohydrates)

I checked several times if sending/receiving SMS costs. As the result of checking my bills, no charged was found. It is because the phone that sends and receives the SMS is the same.

Due to the different characteristic of food items between in Norway and Korea, 3 are only valid for Norwegian version.

B. Norwegian version

There are two different meal types (Bread Meal or Dinner) in Norway and food items can vary depending on the meal types. This program is for bread meals and next step is the application for dinner meals.

How much carbohydrate - a day? - a meal?

Example)

Required energy per day: 2000 kcal
Recommended energy percentage by carbohydrate: 45 ~ 60 %
Obtained energy by 1g carbohydrate = 4 kcal
Required carbohydrates: 225g - 300g per day
Divided into 4 meals: 50g ~ 80g per meal

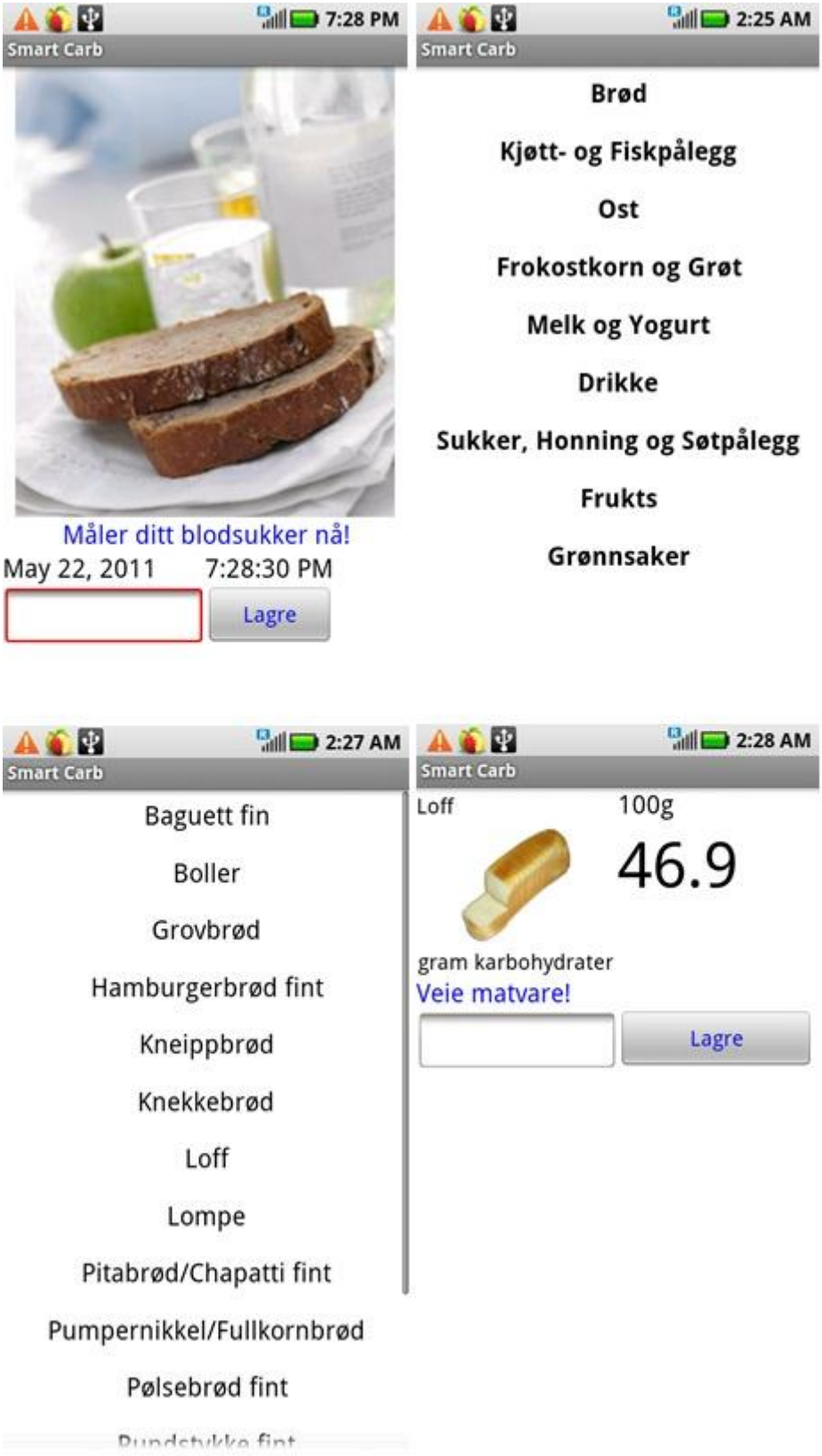

Figure 24. Measure blood glucose level before meal and choose food items (Norwegian)

Figure 25. Check amount of carbohydrate and set stopwatch (Norwegian)

Figure 26. Measure blood glucose level after meal and checks the change with food list (Norwegian)

Figure 27. Several food items (Norwegian)

C. Korean version

How much carbohydrate per day or per meal

Recommended calories from carbohydrate = 60-65% of total required calories per day

Daily carbohydrate requirement = Calories from carbohydrate intake / 4

For example, men who consumed a day 1800kcal
1800 X 06. ~ 0.65 = 1080 ~ 1170kcal → Recommended calorie from carbohydrate per day
1080 ~ 1170 / 4 = 270 ~ 292.5g → Recommended amount of carbohydrate per day
Divided into 3 meals → 270 ~ 292.5 / 3 = 90 ~ 97.5g → Recommended carbohydrate per meal

Figure 28. Measure blood glucose level before meal and choose food items (Korean)

Figure 29. Check amount of carbohydrate and set stopwatch (Korean)

Figure 30. Measure blood glucose after meal and checks the change with food list (Korean)

Figure 31. Several food items (Korean)

5.5 Summary

Firstly, this chapter describes the design goals and considerations.

Searching and recording, database and calculating, and registration were considered as important parts for designing. Text, font (size and colour), and picture were taken into design variables to enhance the usability of the application.

This chapter provides step by step description as to how the prototypes were developed. Excel was introduced as a good tool to make prototypes. Meeting with nutritionist and feedback from a real living patient with diabetes helped to see the problems from the user's point of view. The process of development is described with pictures of the all prototypes.

Next, this chapter illustrates the design of application. A simple model with basic food items were developed to check the application's usability first. Then categorizing and selecting the food items were conducted as described.

Lastly, this chapter describes the actual applications (Norwegian and Korean versions) with the way to use this system. Screen shots are presented to describe the process better.

Chapter 6

Implementation

The implementation was done using 'Block programing language' in App inventor.

Seymour Papert (67) mentioned about the advantage of programing using App Inventor like below.

"The educational perspective that motivates App Inventor holds that programming can be a vehicle for engaging powerful ideas through active learning. As such, it is part of an on-going movement in computers and education that began with the work of Seymour Papert and the MIT Logo Group in the 1960s."

6.1 Programming language

As I mentioned in method part, App inventor programming language is closely related to Scratch.

6.1.1 Scratch programming language

Maloney et al. (68) mentioned that Scratch is a visual programming environment that allows users to learn computer programing, and supporting self-directed learning through tinkering and collaboration with peers is the main design goal of Scratch.

Scratch programing language allows people to develop applications by assembling visual blocks to control images, music and sound (69). By the Lifelong Kindergarten Group at the MIT Media Lab led by Mitchel Resnick and with financial support from the National Science Foundation, Microsoft, Intel Foundation, MacArthur Foundation, Google, Iomega and MIT Media Lab research consortia, scratch programing was developed (70). In any Computer Operation System environment includes Windows, Mac OS X or Linux, scratch can be installed and freely redistributed, and it is possible for non-commercial users to modify the source code.[7]

[7] http://info.scratch.mit.edu

6.2 Flow chart

Here is the flow chart for the Smart Carb Norwegian version. For the food items in 'Drink' and 'Milk and Yogurt' categories, empty glass should be weighed first, before the food item with glass are weighed.

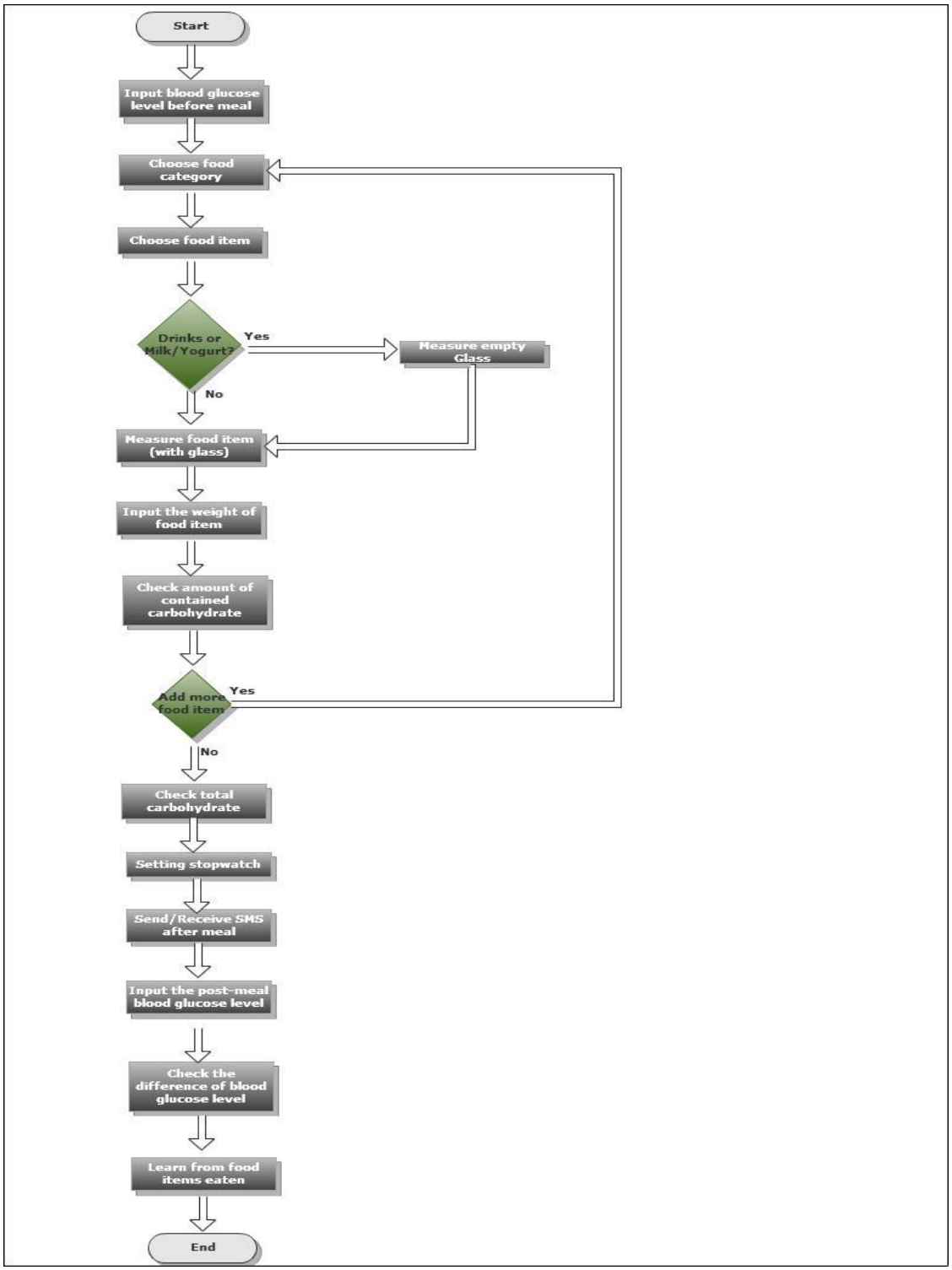

Figure 32. Flow chart for Norwegian version

The Korean version of Smart Carb is presented like below. The difference is there is no process of weighing food items in Korean version. Thus there is no process of weighing empty glass, either. Due to the characteristic of Korean dishes, it is difficult to weigh the food items. Instead of weight, standard portion sizes are displayed with the amount of contained carbohydrates of food items.

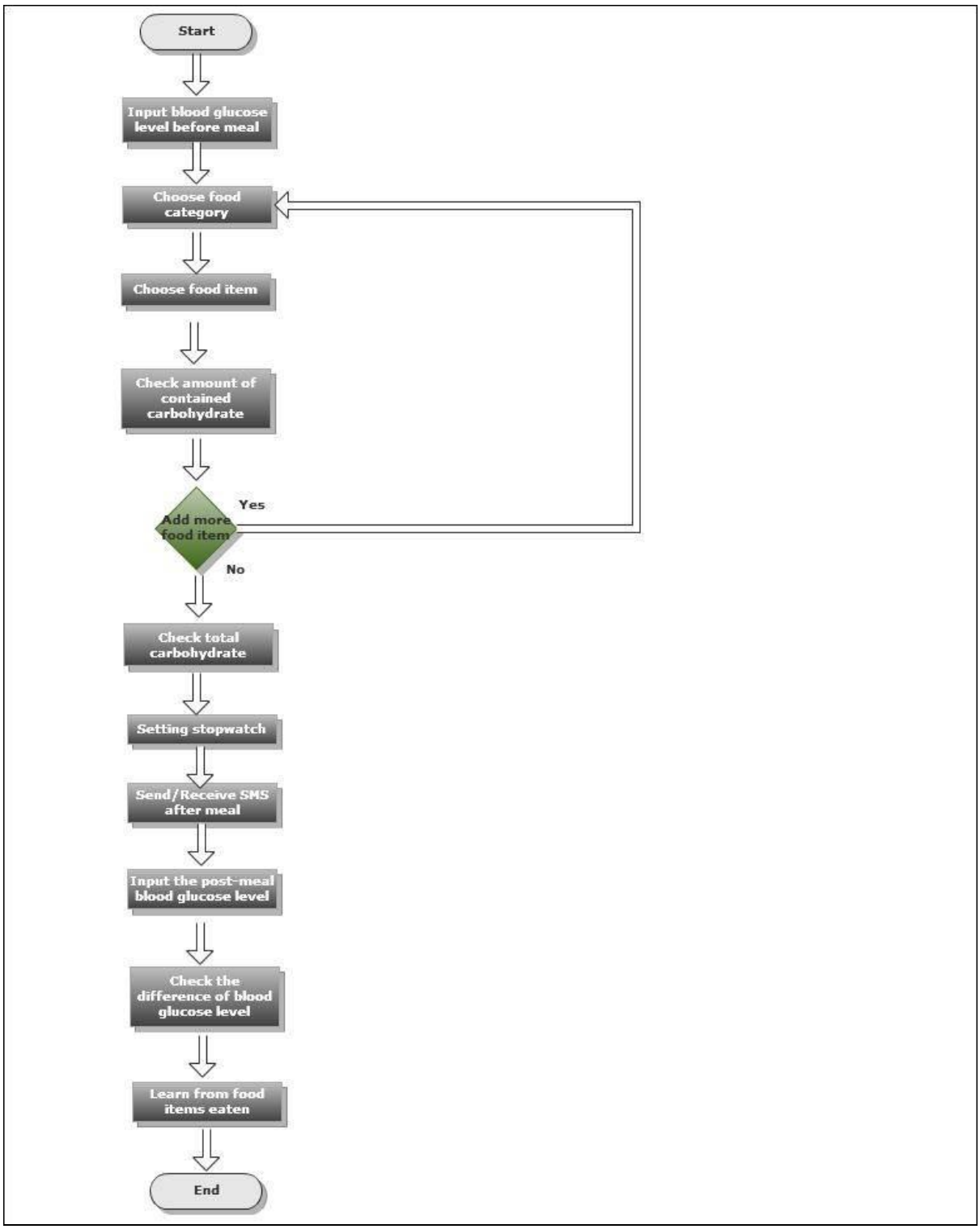

Figure 33. Flow chart for Korean version

6.3 Visual blocks programming

Visual blocks programming window can be opened by clicking the button 'Open blocks editor' on the App Inventor web browser.

6.3.1 Implement requirement for app inventor

System requirements:

A. Computer and operating system

Macintosh (with Intel processor): Mac OS X 10.5, 10.6
Windows: Windows XP, Windows Vista, Windows 7
GNU/Linux: Ubuntu 8+, Debian 5+

B. Browser

Mozilla Firefox 3.6 or higher
Apple Safari 5.0 or higher
Google Chrome 4.0 or higher
Microsoft Internet Explorer 7 or higher

Software requirements:

A. Java configuration : Java 6 JDK
B. App Inventor Setup Software
C. A Google App Inventor Beta Account

6.3.2 Design and open block programming

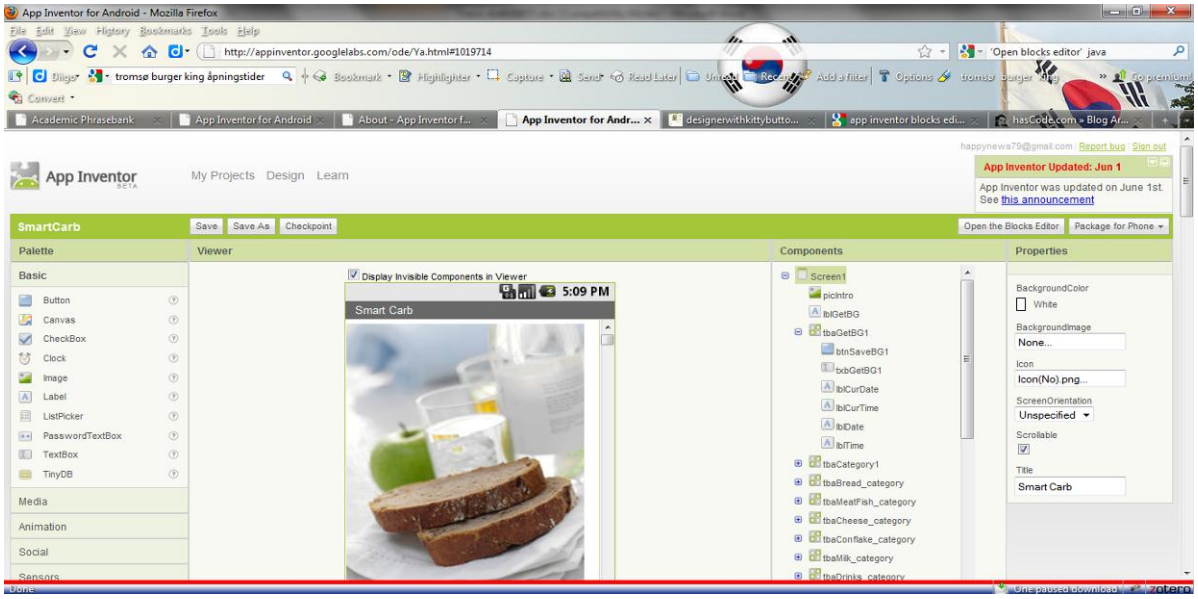

Figure 34. App inventor designer web browser

Various components for programing such as textbox, label, image, button, etc. can be found on the left side of app inventor designer web browser. To use the components, users can just drag and drop the components to the screen in the middle. Properties of the components can be modified on the right side of App Inventor designer web browser.

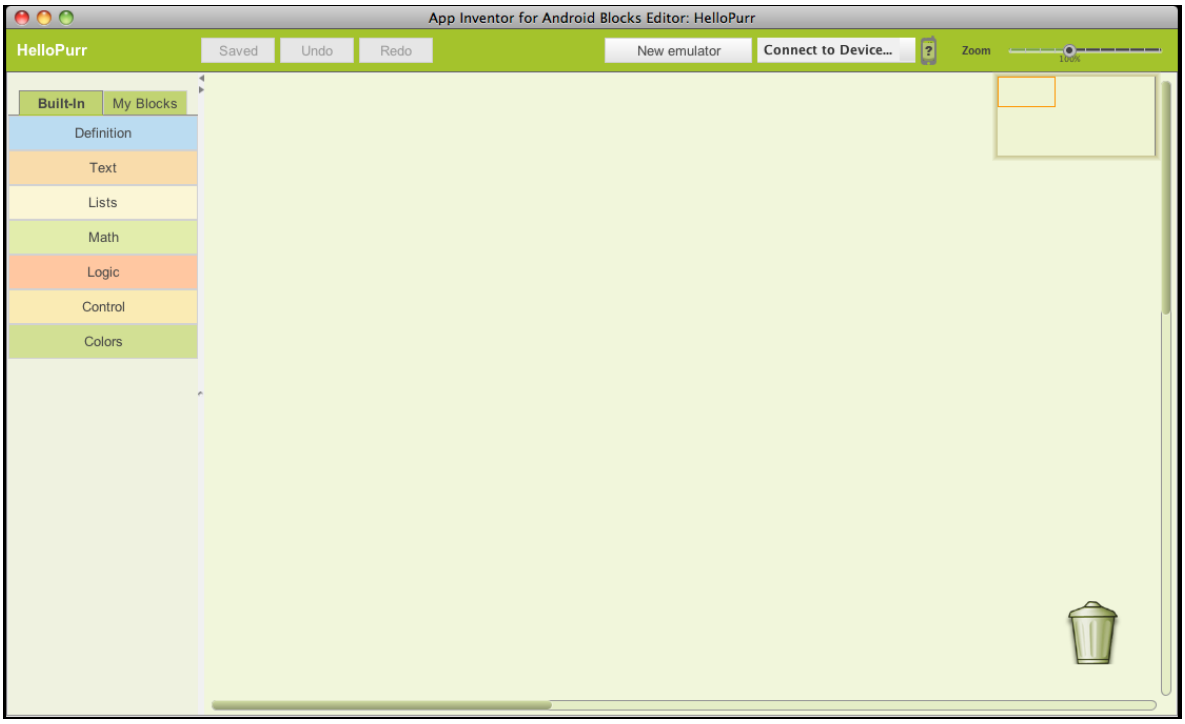

Figure 35. Empty open block editor

By clicking the button 'Open the blocks editor' which is located in the right-up side of the App Inventor designer web browser, the blocks editor can be started. Blocks can be dragged to the empty space from the left side of the Blocks editor. The blocks can be assembled in the empty canvas. However the blocks are generated based on the components which were implemented in the App Inventor designer browser.

6.3.3 Deploy and run

Three different ways exist to deploy the application which is developed through App Inventor.

- QR code

QR code can be shown on the monitor to download the application into the phone

- Apk file

Apk file can be downloaded to computer

- Application itself

Application can be downloaded directly to phone through USB cable

6.3 Codes

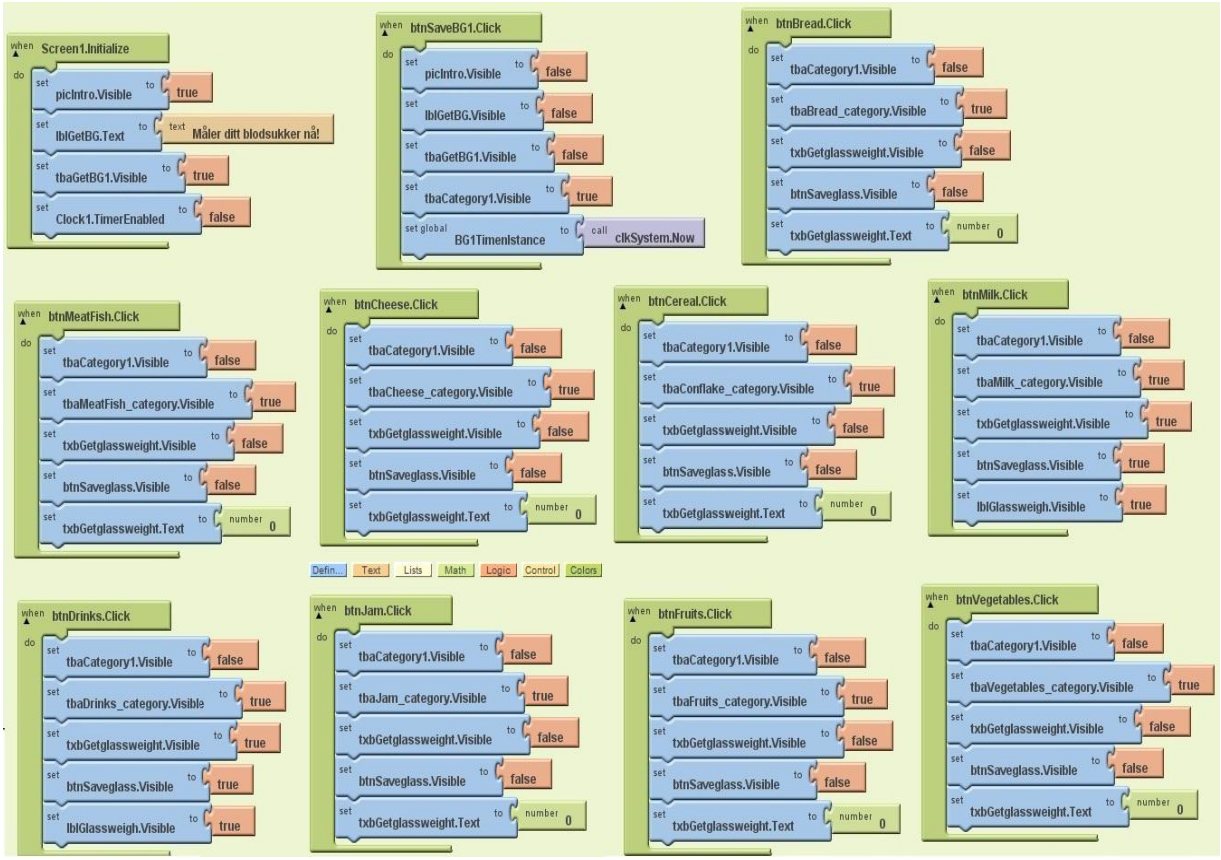

Figure 36. Visual blocks programming code for food categories (Norwegian)

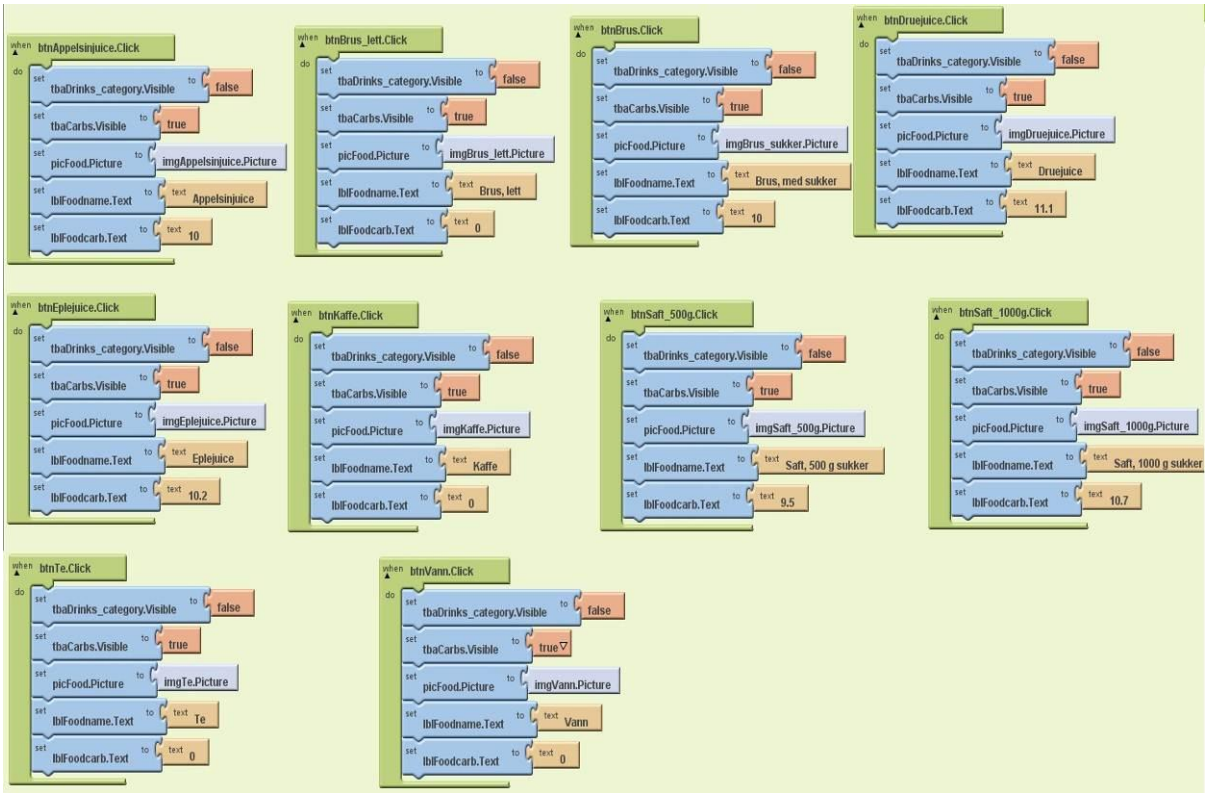

Figure 37. Visual blocks programming code for food items – Drinks and Jams (Norwegian)

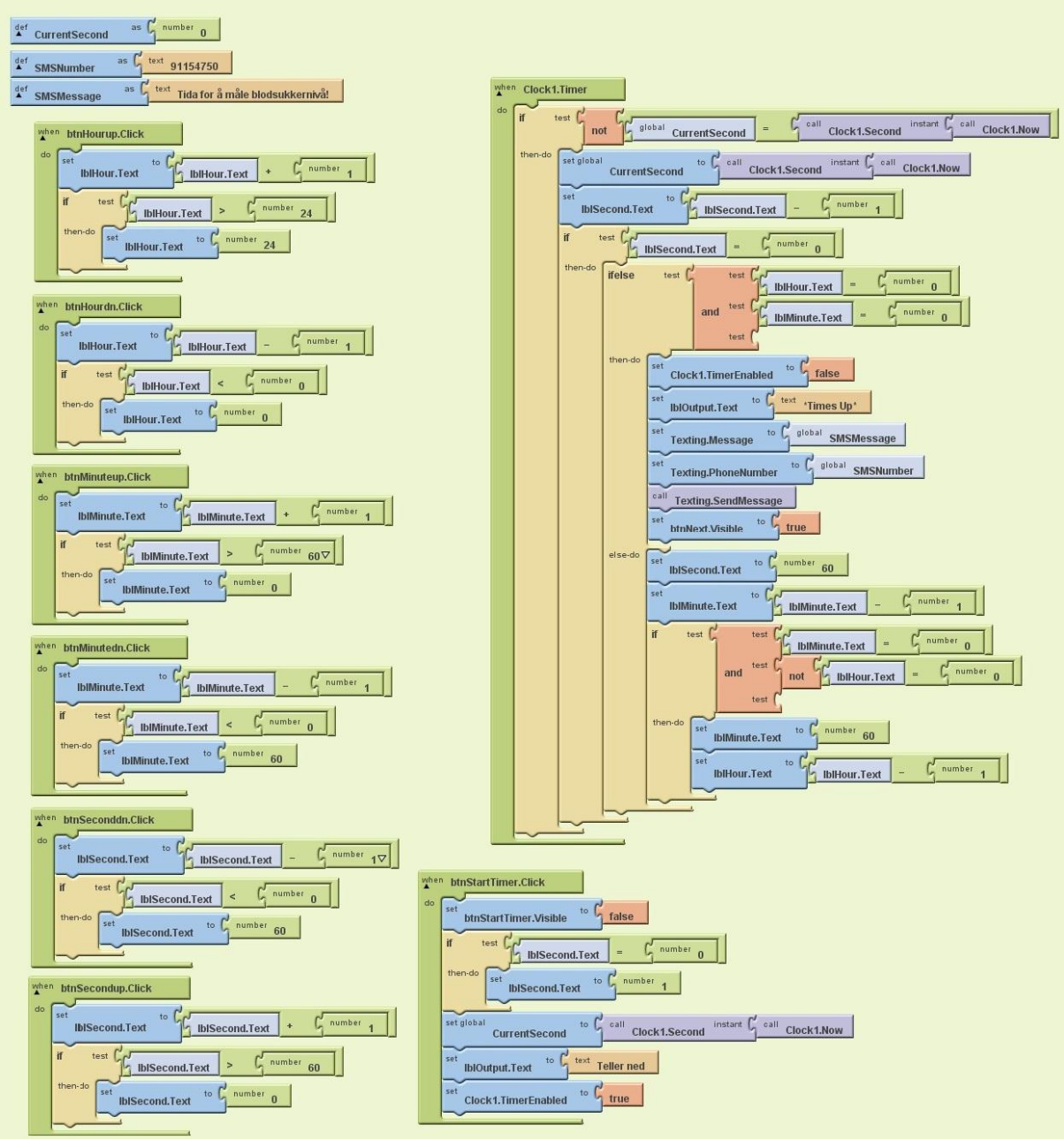

Figure 38. Visual blocks programming code for stop watch (Norwegian)

6.4 Summary

This chapter describes the process of implementation.

First, the introduction of the programming language that was used is provided. Flow charts in this chapter help to see all the system process and how it is operated. The environment of implementation such as system requirement and software requirement are explained as well.

Later, this chapter describe the tools for designing and programming, and introduce how to deploy and run the developed system.

Lastly, some codes for this application were illustrated with screen shots of the programing tool.

Chapter 7

Test and result

This chapter deals with the result of the test that was conducted. The test includes questionnaire, a presentation about 'carbohydrate counting', a presentation about 'Smart Carb application', usability test and verbal questions about the system. These are explained in this chapter.

7.1 Test result from questionnaire

Before 'Carbohydrate counting' and 'Smart Carb application' were introduced, the sheets of questionnaire were distributed to the participants.

7.1.1 General

General questions such as gender, age, use of insulin, tablet were asked first. However their names were not asked in order to protect the patient information. Patient information is confidential and should be dealt with very carefully.

(1) Gender

Among 7 participants, 6 people were male and 1 was female in the test in Norway (Figure 39). In the test in South Korea, 11 people were male and 9 were female among the 20 participants (Figure 39).

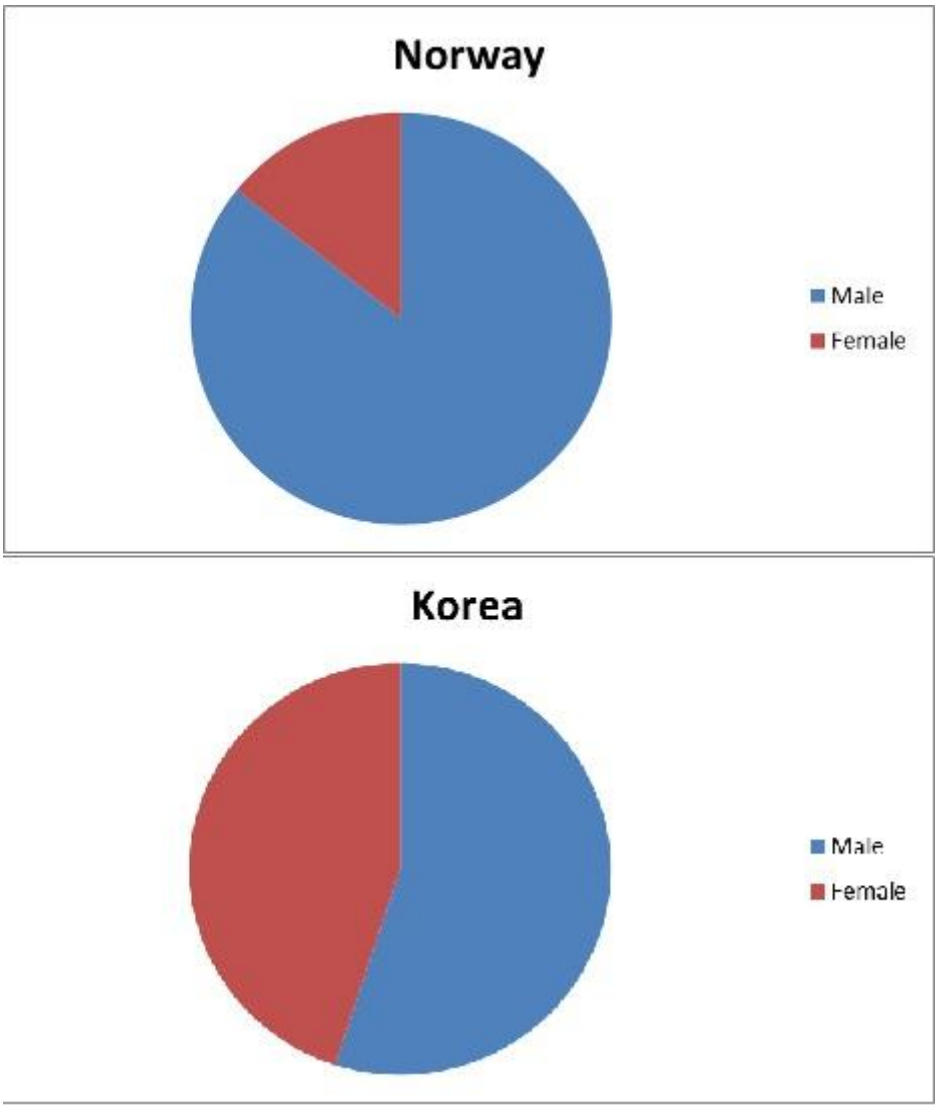

Figure 39. Pie chart of gender among participants

(2) Age

Mean age was 61.428 in Norwegian group and 59.1 in Korean group (Figure 40 and 41).

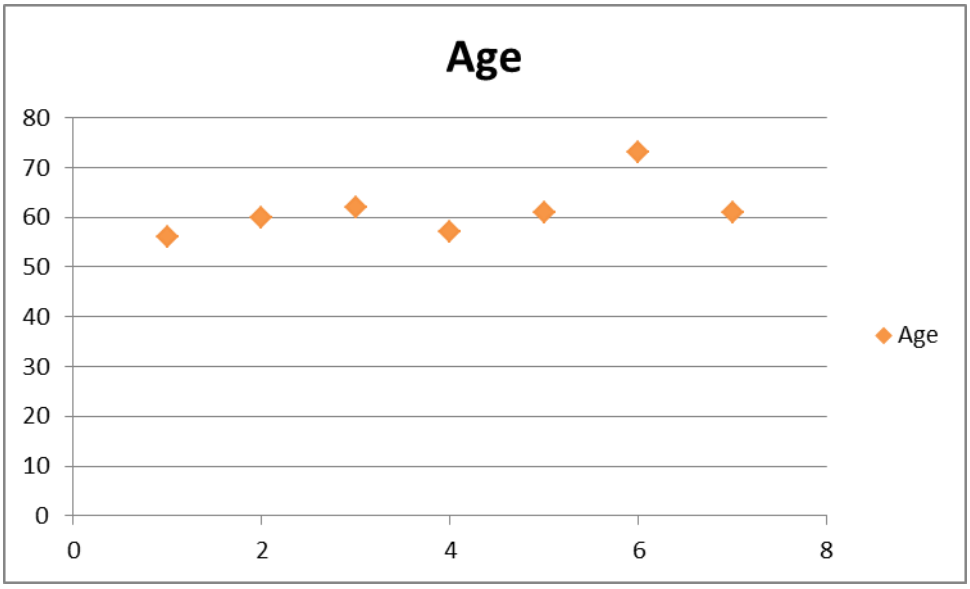

Figure 40. Age Scatter graph in Norwegian participants

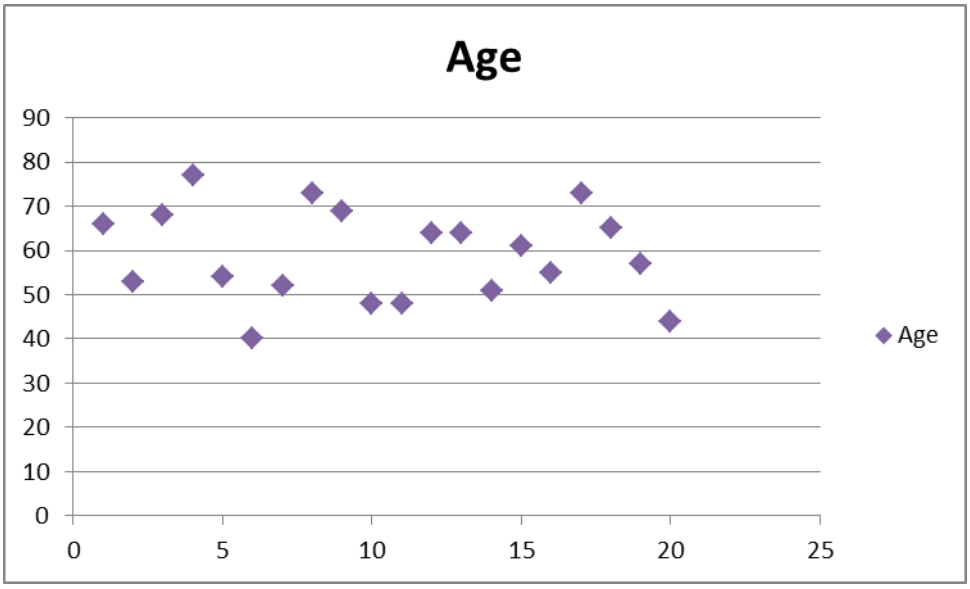

Figure 41. Age Scatter graph in Korean participants

(3) Number of year since first diagnosed as diabetics

Among 7 participants in Norway, 4 people had diabetes for more than 10 years. 1 person was dignosed 5 years ago, 1 person 4 years ago and another person 2 years ago (Figure 42).

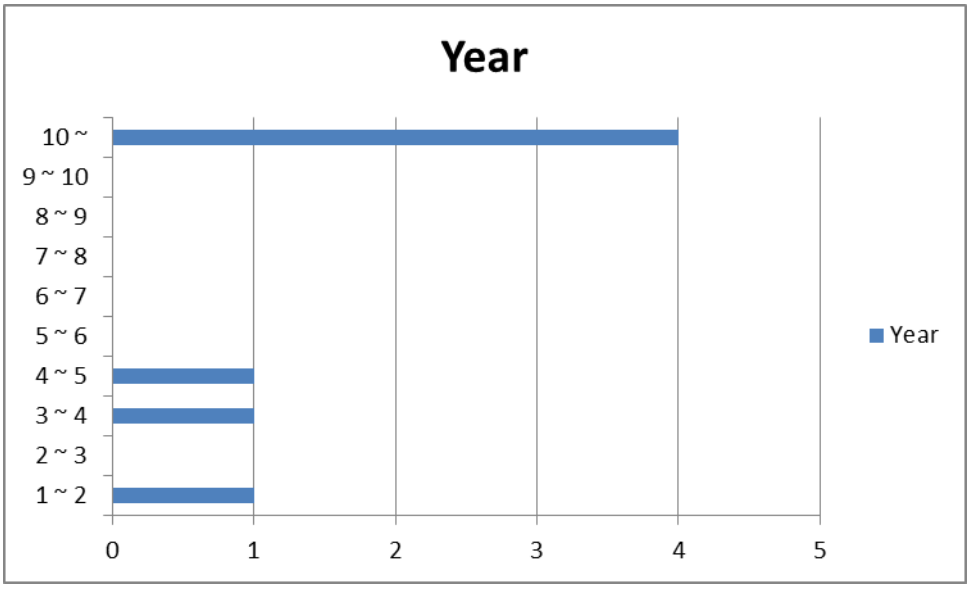

Figure 42. Number of year since diagnosed (Norway)

Among the 20 participants in South Korea, 3 people had diabetes for more than 10 years. 2 people were dignosed 10 years ago, 1 person 9 years ago, 2 people 8 years ago, 1 person 7 years ago, 2 people 6 years ago, 5 people 5 years ago, 2 people 4 years ago, 2 people 2 years ago (Figure 43).

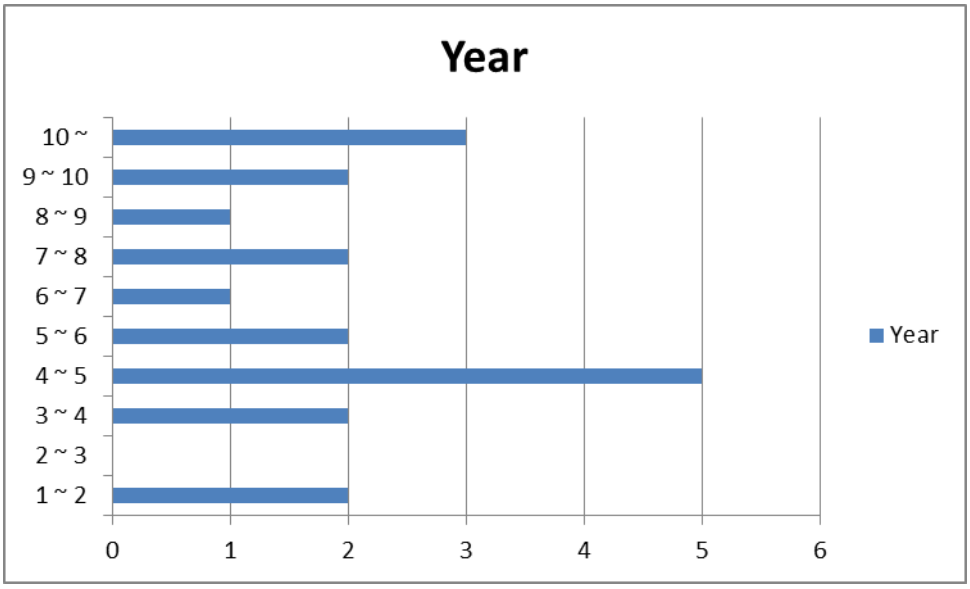

Figure 43. Number of years since diagnosed (Korea)

(4) Insulin

Among the 7 Norwegian participants, 3 people were using insulin and 4 other people were not using insulin (Figure 44).

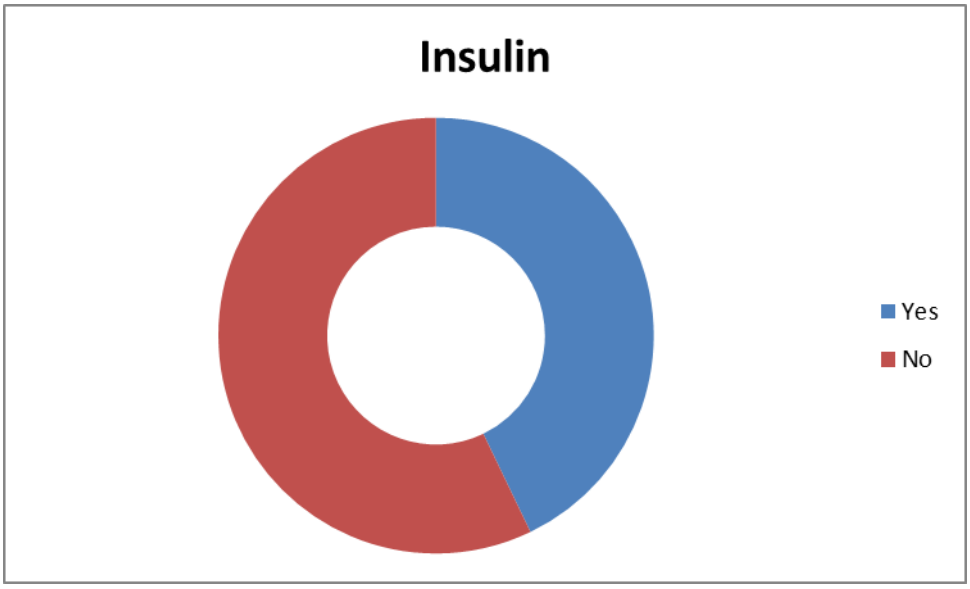

Figure 44. Insulin (Norway)

14 people were not using insulin and 6 other people were using insulin among 20 Korean participants (Figure 45).

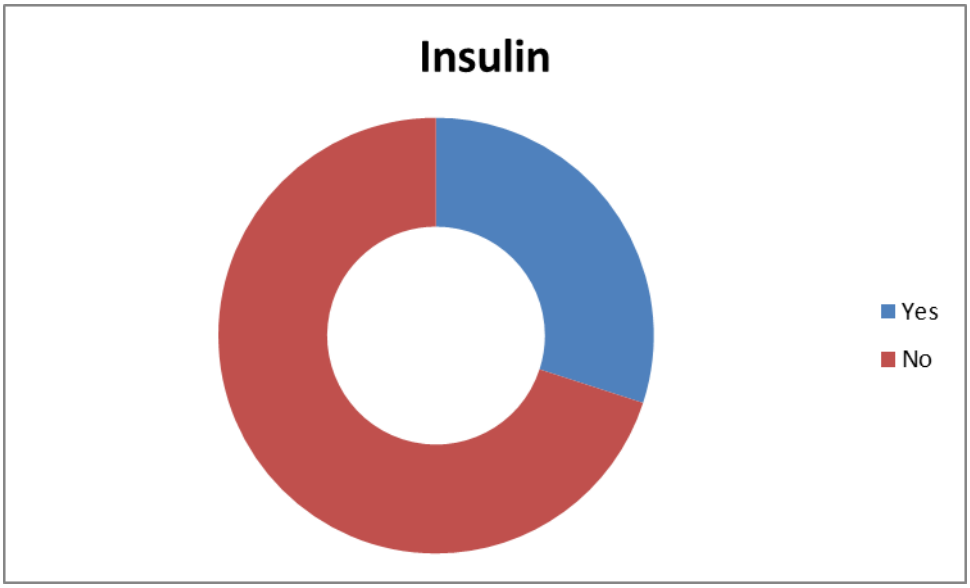

Figure 45. Insulin (Korea)

(5) Tablet

At the test in Harstad, it was investigated that 71.33% of participants were taking tablets and 28.57% of participants were not taking tablets. 5 among the 7 Norwegian participants were taking tablets (Figure 46).

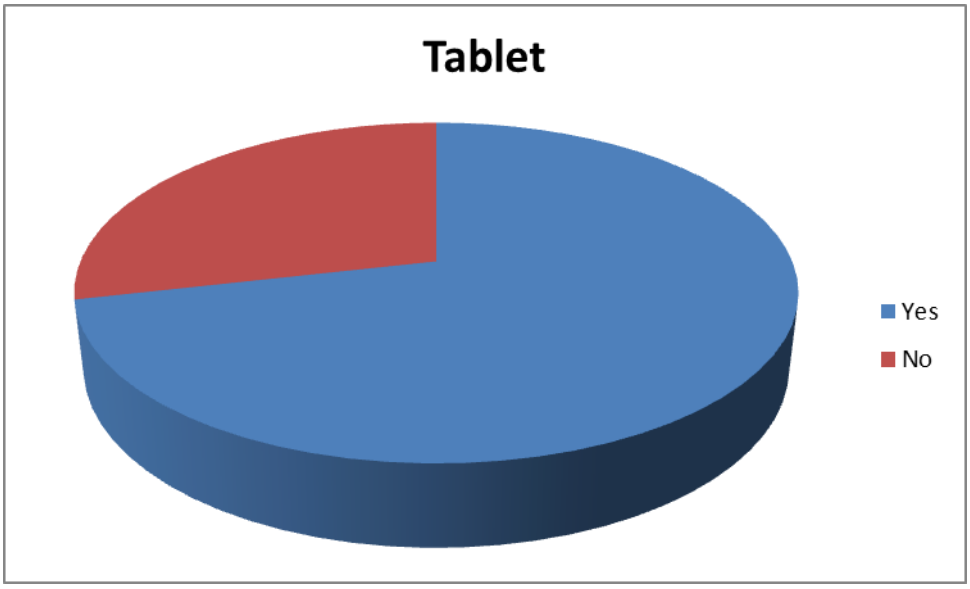

Figure 46. Tablet (Norway)

At the test in Seoul, it was investigated that 75% of participants were taking tablets and 25 % of participants were not taking tablets. 15 of the 20 Korean participants were taking tablets (Figure 47).

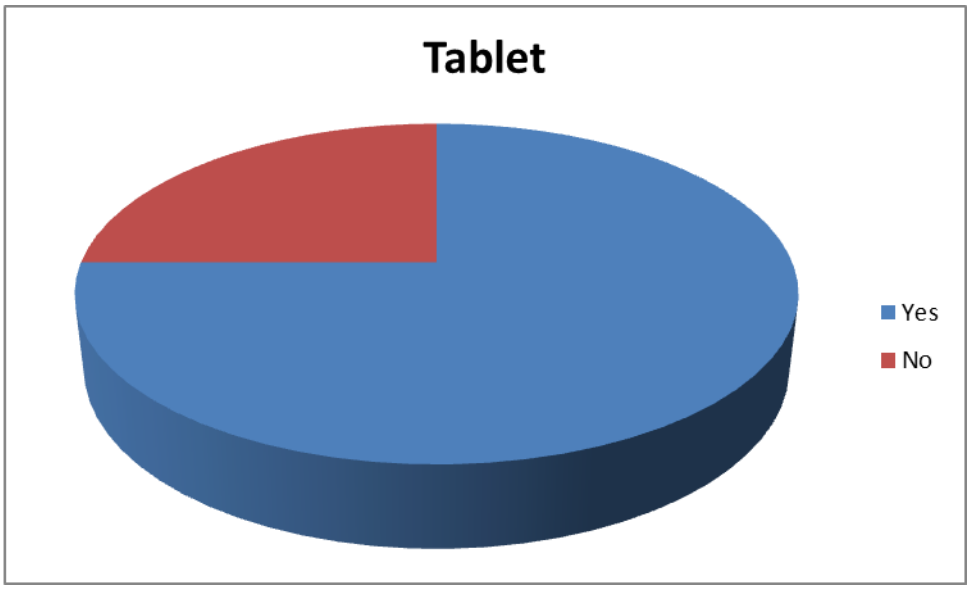

Figure 47. Tablet (Korea)

7.1.2 Blood glucose control

Four questions regarding blood glucose level controlling were asked through the

questionnaire sheet.

(1) Satisfaction with blood glucose level self-control

71.33% of Norwegian participants were satisfied with their blood glucose level self-controlling, and 28.57% of Norwegian participants were not satisfied with their blood glucose level self-controlling (Figure 48).

Figure 48. Satisfaction with blood glucose level self-control (Norway)

80% of Korean participants were not satisfied with their blood glucose level self-controlling and only 20% of Korean participants were satisfied with their blood glucose self-controlling (Figure 49).

Figure 49. Satisfaction with blood glucose level self-control (Korea)

(2) Hard to control blood glucose level and the reason

One Norwegian participant answered that controlling blood glucose level is difficult because of other pills which were taken to treat other diseases. 85.71% of Norwegian participants (6 among 7 people) answered that blood glucose control is not difficult for them (Figure 50).

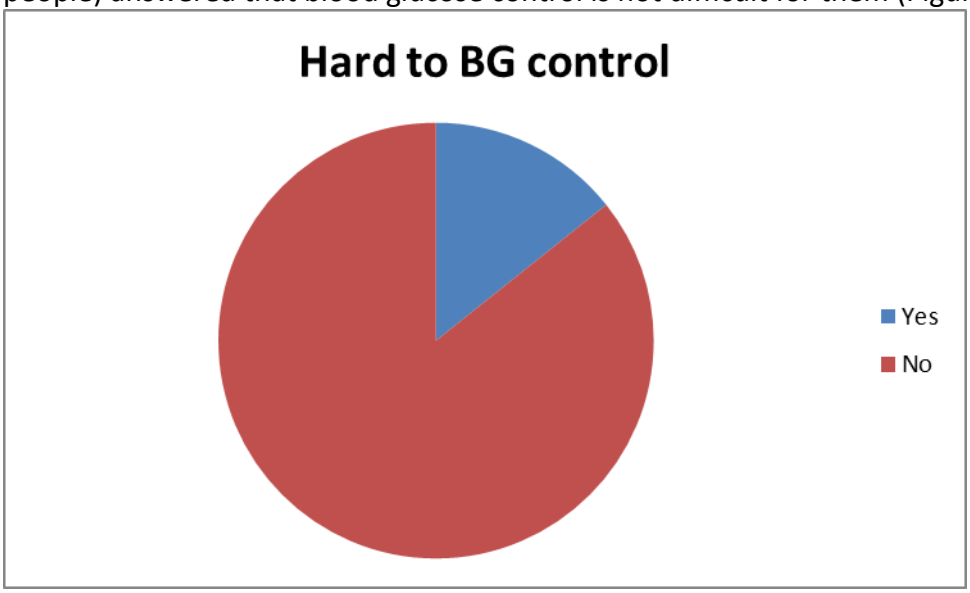

Figure 50. Hard to control blood glucose level (Norway)

However among 20 Korean participants, only 4 people (20% of participants) answered that blood glucose controlling is not difficult for them. The rest, 16 other people (80% of participants) answered that blood glucose controlling is difficult for them (Figure 51). The reasons were difficulty to manage nutrition, lack of activities, difficulty to anticipate the level and difficulty to manage at work. The most frequent reason was difficulty to manage nutrition.

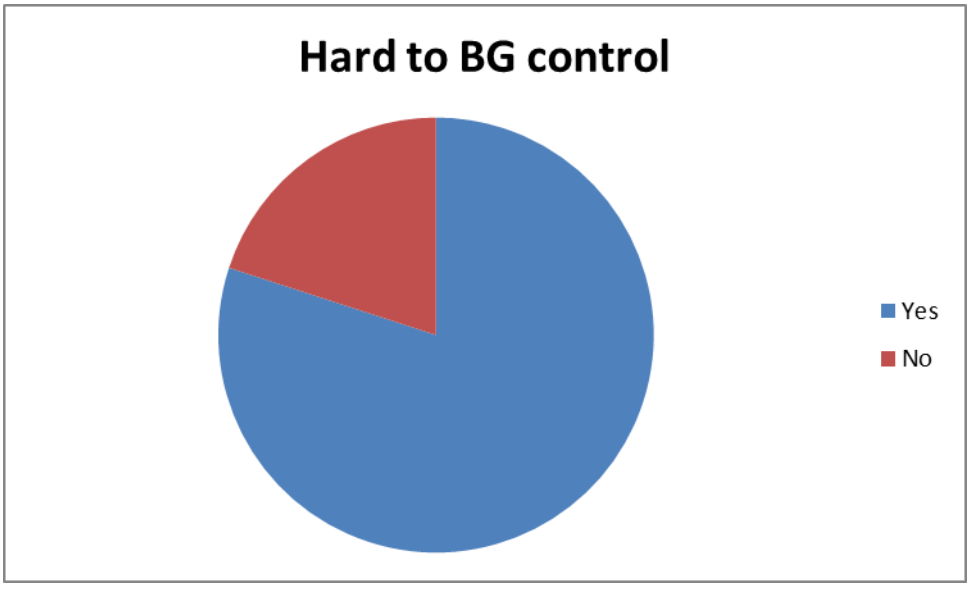

Figure 51. Hard to control blood glucose level (Korea)

(3) Number of measuring blood glucose level

Table 8. Number of measuring blood glucose level

	Once a month	Once a week	One per two days	1 ~ 2 a day	3 ~ 4 a day	Over 5 a day
Norway				4	2	1
Korea	5	5	1	6	2	1

57.14% of Norwegian participants answered that they measured their blood glucose levels 1~2 times per day. 28.57% of the participants said 3~4 times a day and 14.29% of the participants said over 5 times a day (Table 9 and Figure 52).

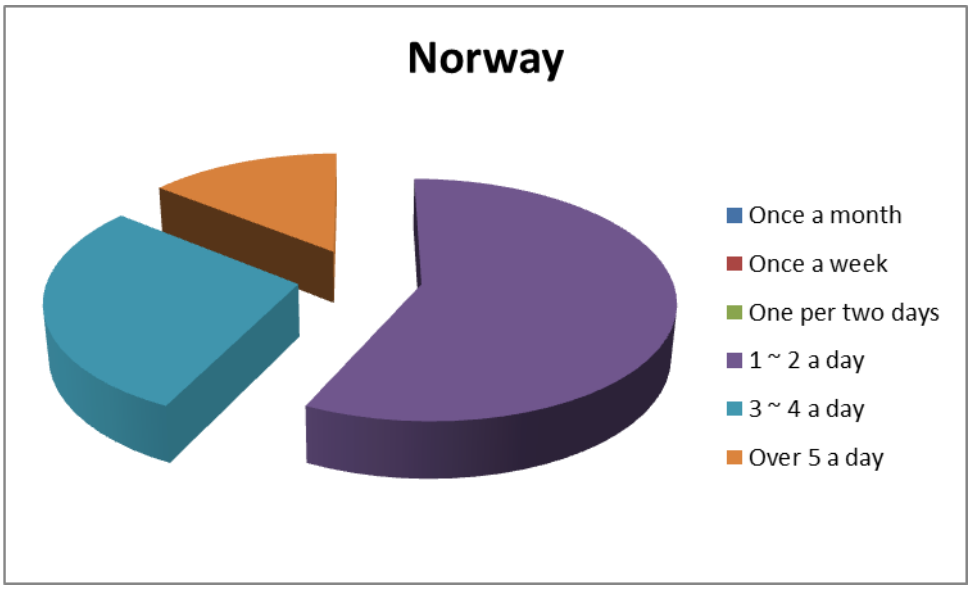

Figure 52. Frequency of measuring blood glucose level (Norway)

30% of the Korean participants answered that they measured their blood glucose levels 1~2 times a day. 25% of the participants said once a month and another 25% of the participants said once a week. 5% of the participants said once per couple of day and another 5% of participants said over 5 times per day. 10% of the participants answered they meadured their blood glucose levels 3~4 times a day (Table 9 and Figure 53).

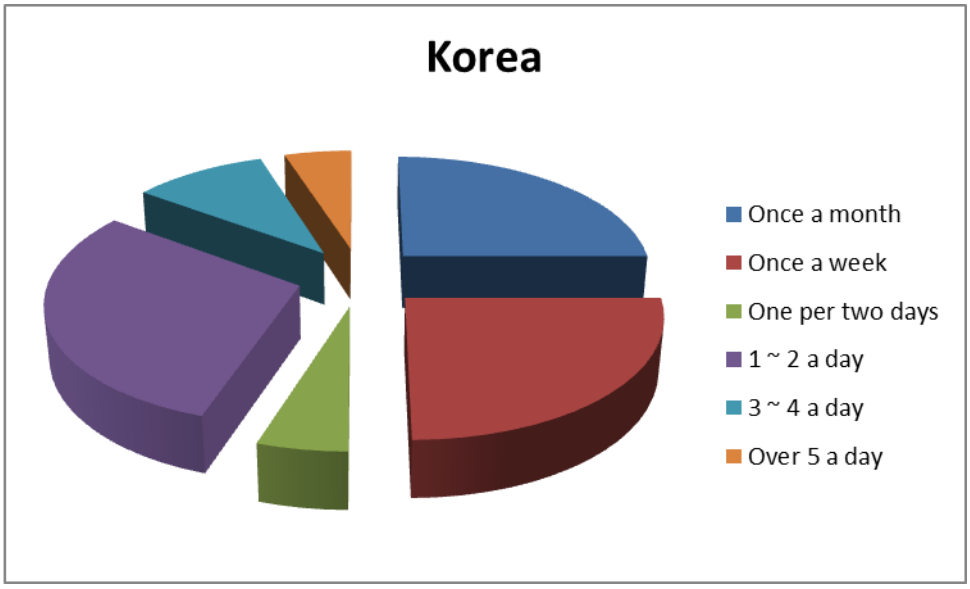

Figure 53. Frequency of measuring blood glucose level (Korea)

(4) Time to measure blood glucose level

All of the Norwegian participants said that they measured their blood glucose levels before breakfast. 15 Korean participants said they measured blood glucose levels before breakfast. However only 1 person among 7 Norwegian participants and 6 people among 20 Korean participants said that they measured blood glucose levels around 2 hours after breakfast.

7.1.3 Carbohydrate counting

(1) Experience

Whether they have tried carbohydrate counting or not was asked. All 7 Norwegian participants said that they had never tried before (Figure 54). However 20% of the Korean participants answered that they had tried carbohydrate counting before (Figure 55).

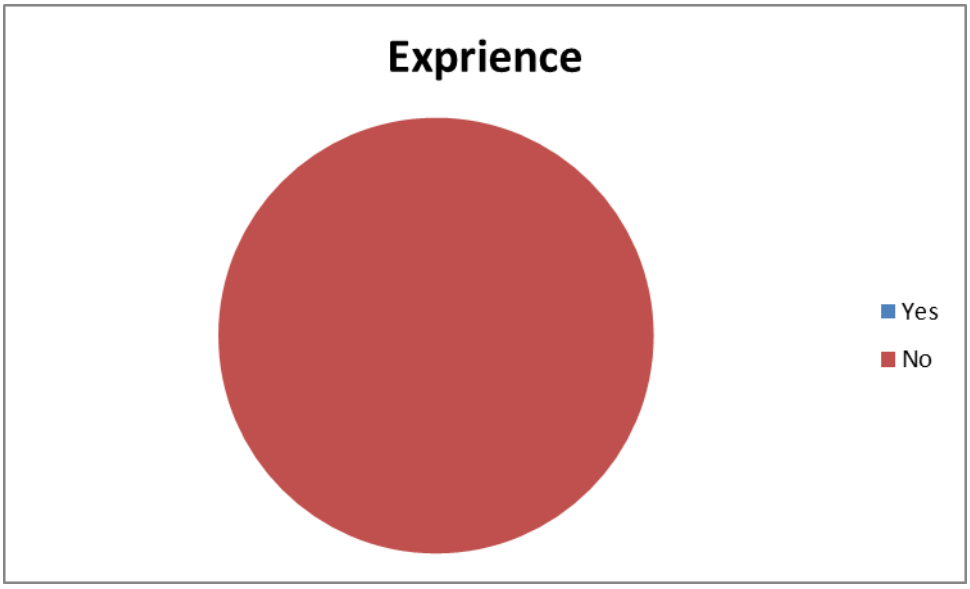

Figure 54. Pie chart of previous experience with carb counting (Norway)

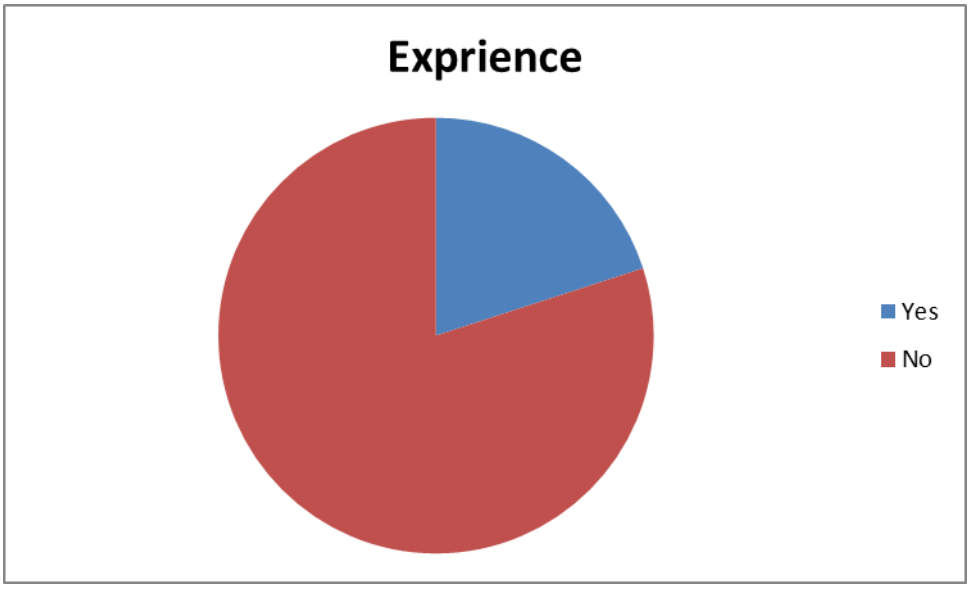

Figure 55. Pie chart of previous experience with carb counting (Korea)

(2) Awareness of carbohydrate counting

Table 10, Figure 56 and 57 show the degree of the participants' awareness about carbohydrate counting.

Table 9. Awareness of carbohydrate counting

	Norway	Korea
Know well	0	0
Know little	4	8
Do not know	3	12

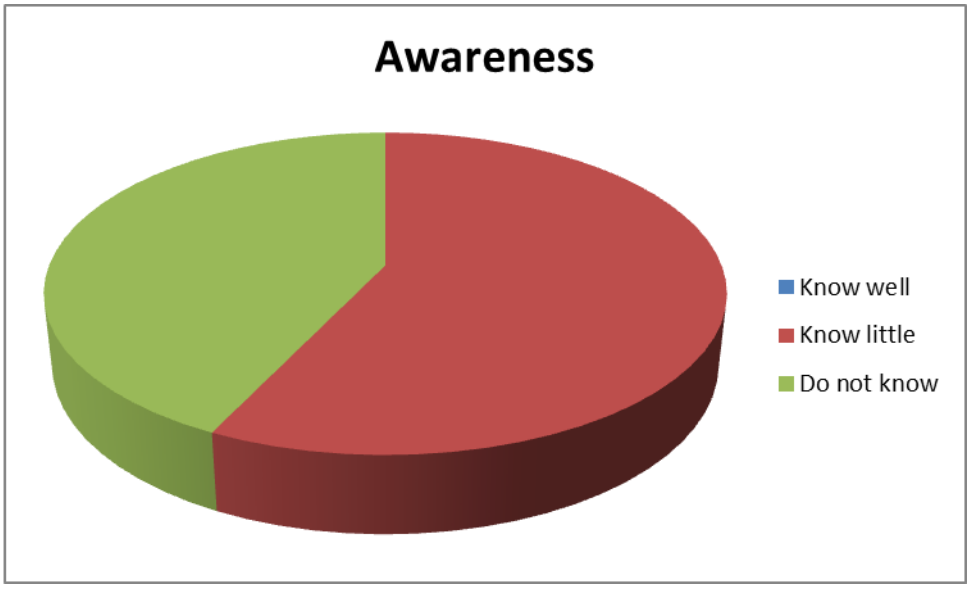

Figure 56. Awareness about carbohydrate counting (Norway)

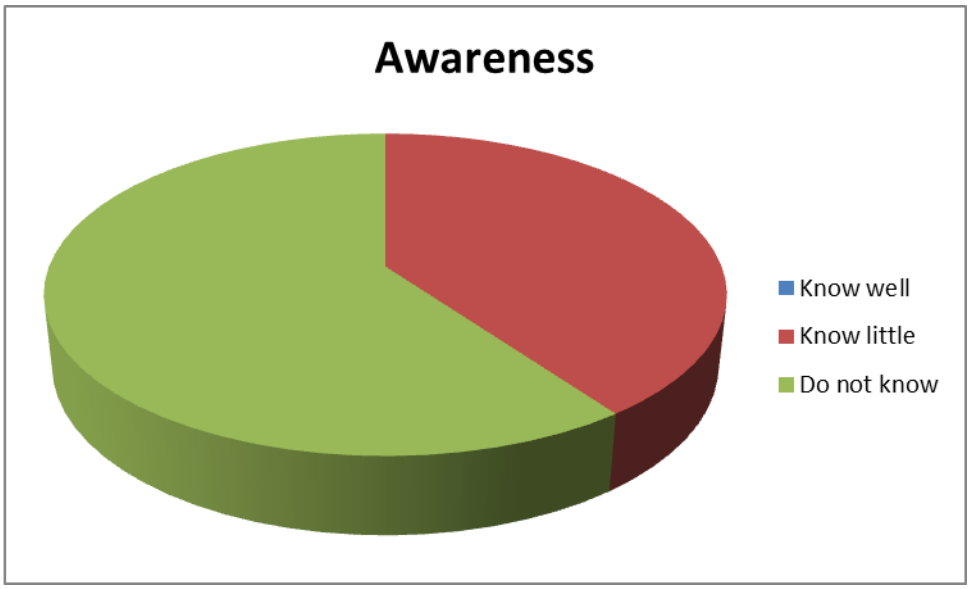

Figure 57. Awareness about carbohydrate counting (Korea)

(3) Estimating carbohydrate amount during meal planning

Table 11, Figure 58 and 59 describe the frequency of estimating carbohydrate before the participants had meals.

Table 10. Frequency of estimating carbohydrate for meal

	Norway	Korea
Very often	0	1
Often	0	1
Occasionally	2	2
Rarely	1	4
Never	4	12

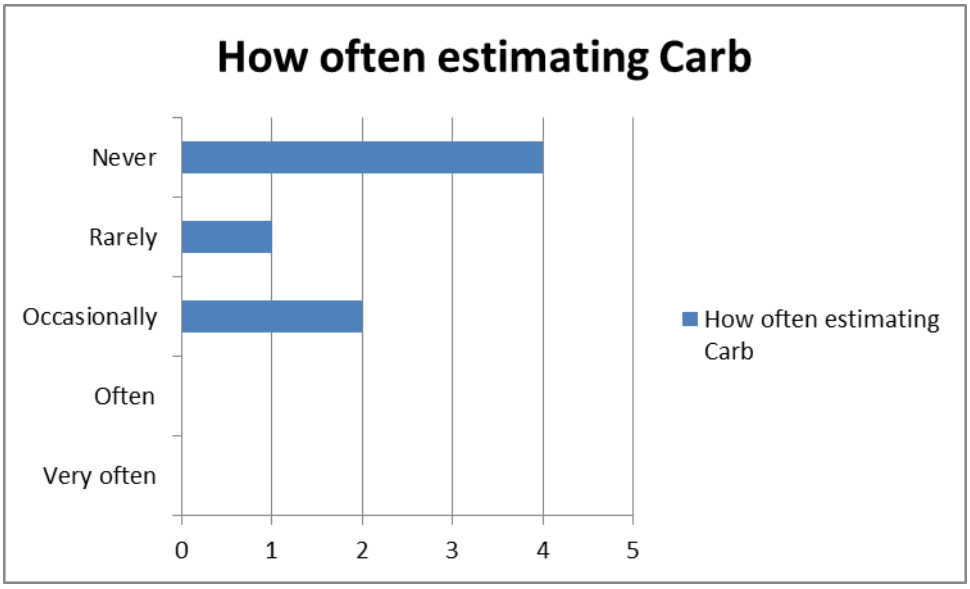

Figure 58. Frequency of estimating carbohydrate for meal (Norway)

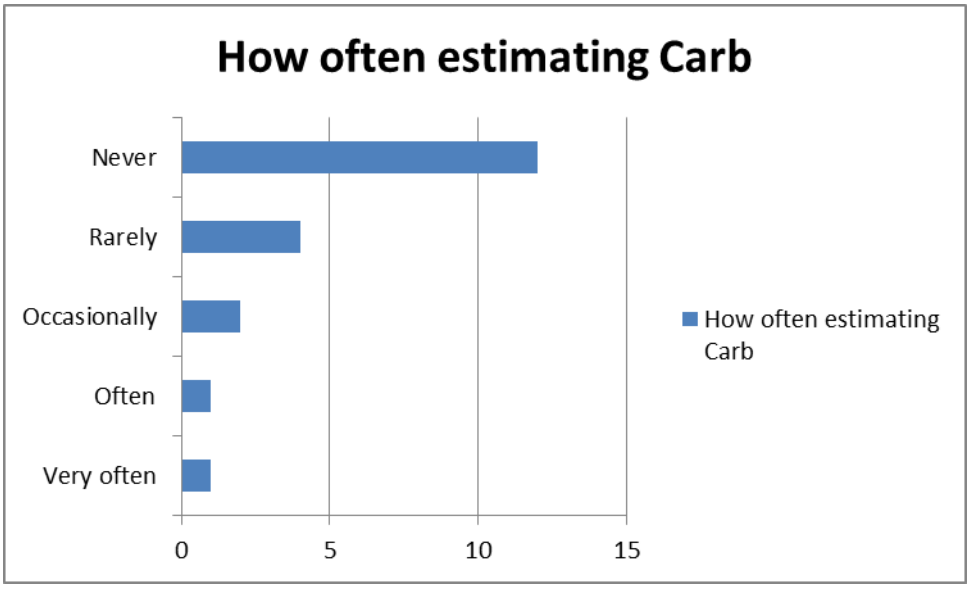

Figure 59. Frequency of estimating carbohydrate for meal (Korea)

(4) Importance of tracing carbohydrate amount

'How important tracing carbohydrate amount is' was investigated. Table 12, Figure 60 and 61 shows the degree of it.

Table 11. Importance of tracing carbohydrate amount

	Norway	Korea
Very important	0	6
Quite important	2	4
Important	2	6
Slightly important	3	2
Not important at all	0	2

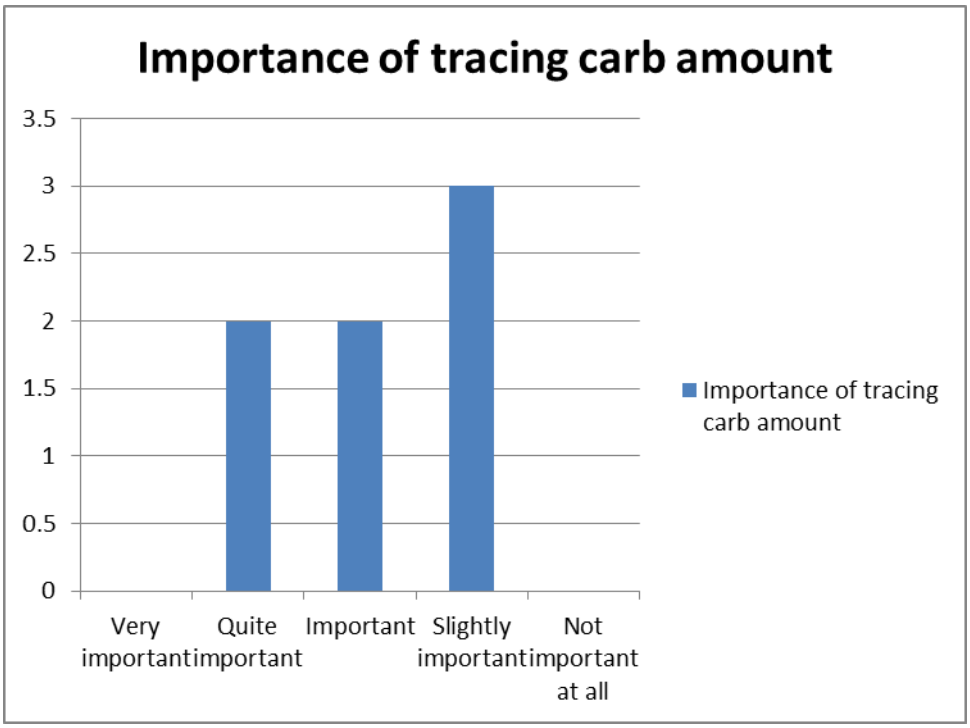

Figure 60. Importance of tracing carbohydrate amount (Norway)

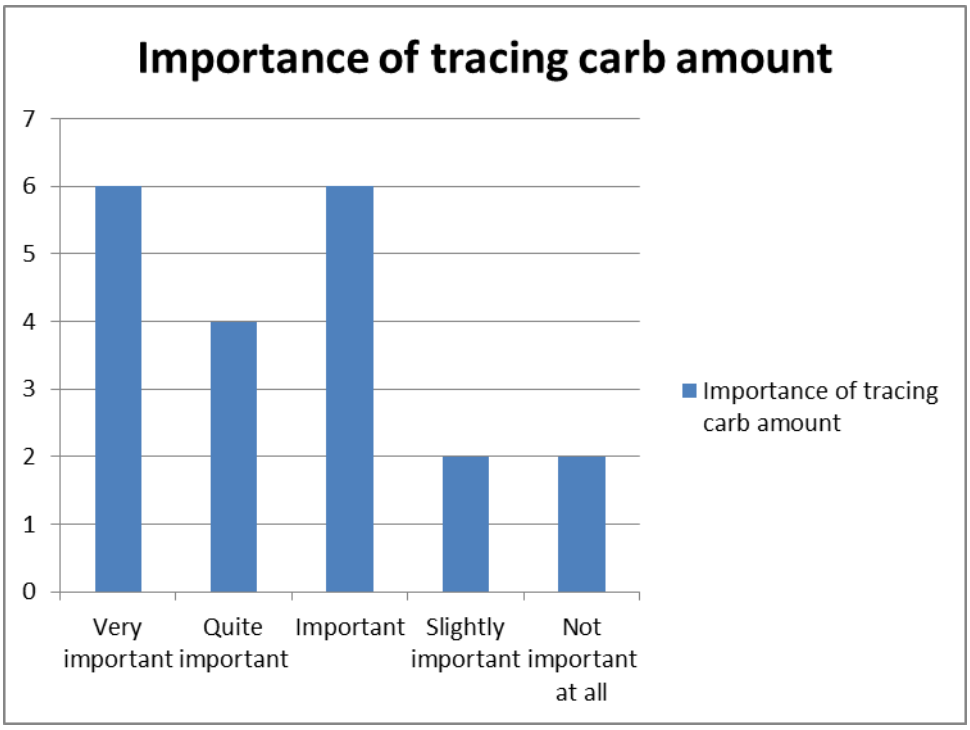

Figure 61. Importance of tracing carbohydrate amount (Korea)

(5) Difficulty of estimating carbohydrate amount

'How difficult estimating carbohydrate amount is' was asked. Table 13, Figure 62 and 63 describe the degree of it.

Table 12. Difficulty of estimating carbohydrate amount

	Norway	Korea
Very difficult	2	8
Quite difficult	0	1
Difficult	5	6
Little bit difficult	0	5
Not difficult at all	0	0

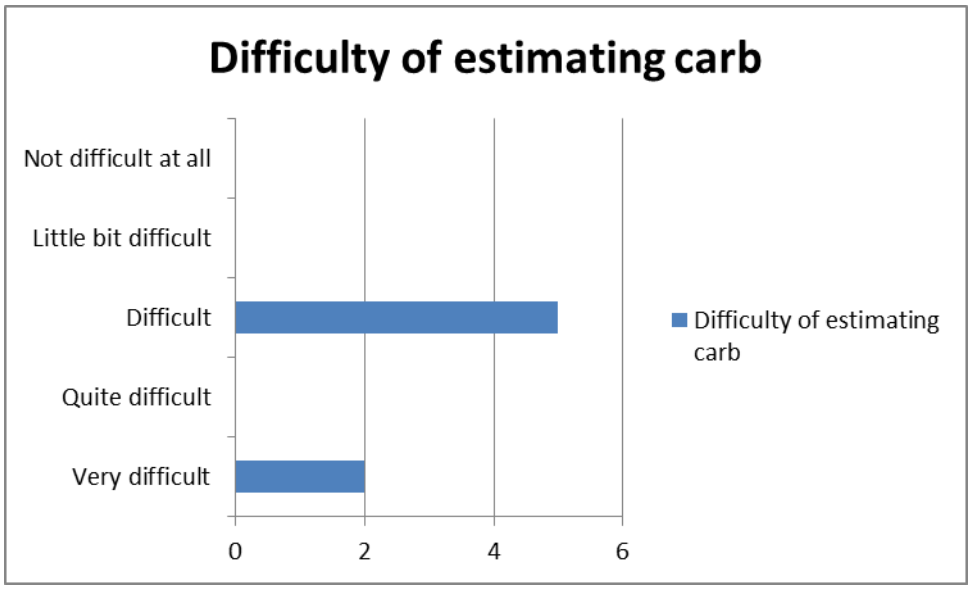

Figure 62. Difficulty of estimating carbohydrate amount (Norway)

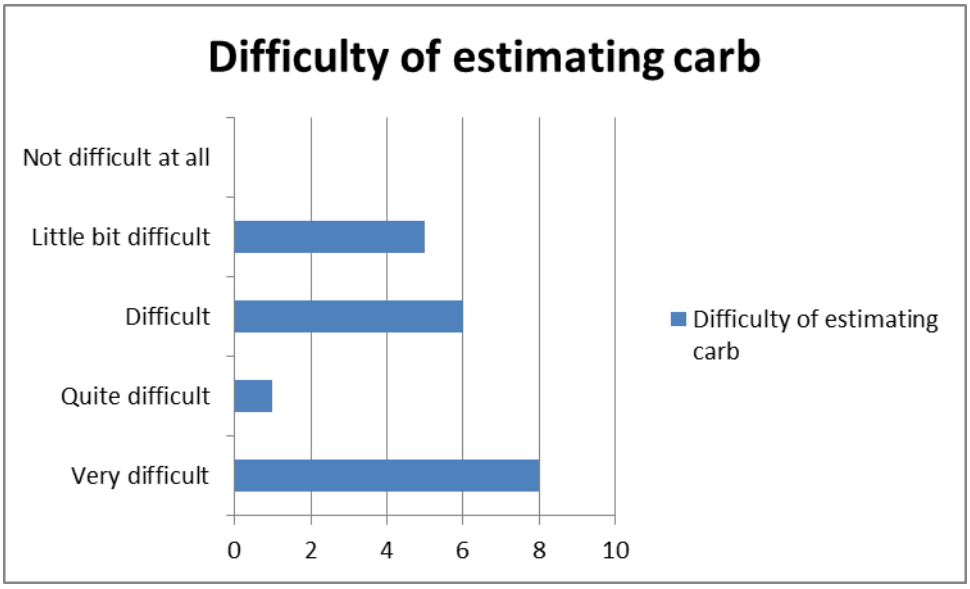

Figure 63. Difficulty of estimating carbohydrate amount (Korea)

(6) Significance of carbohydrate counting application

'How important having a carbohydrate counting application is' was investigated. The degree is shown in Table 14, Figure 64 and 65.

Table 13. Significance of carbohydrate counting application

	Norway	Korea
Very important	2	7
Quite important	3	5
Important	2	6
Little bit importance	0	1
Not important at all	0	1

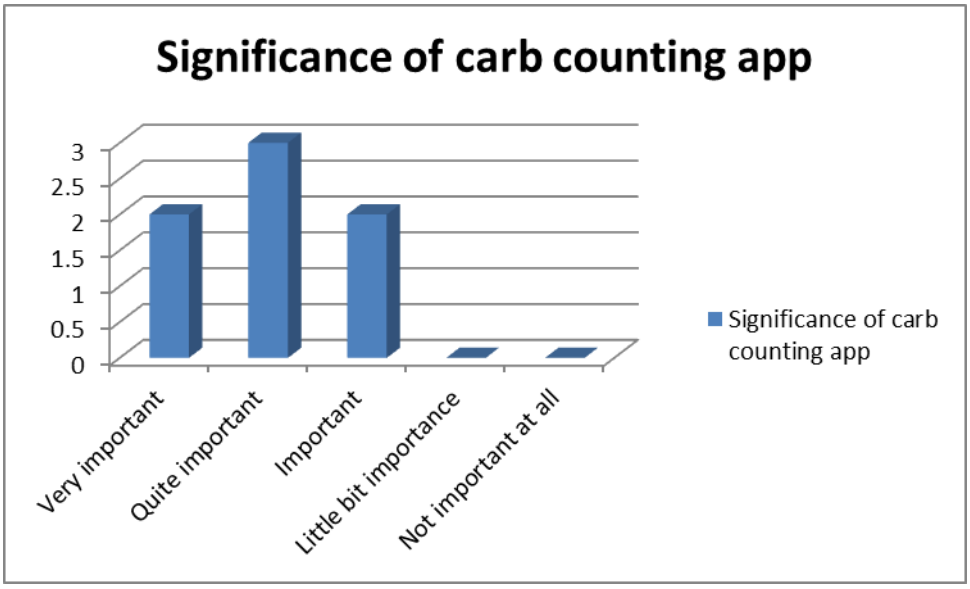

Figure 64. Significance of carbohydrate counting application (Norway)

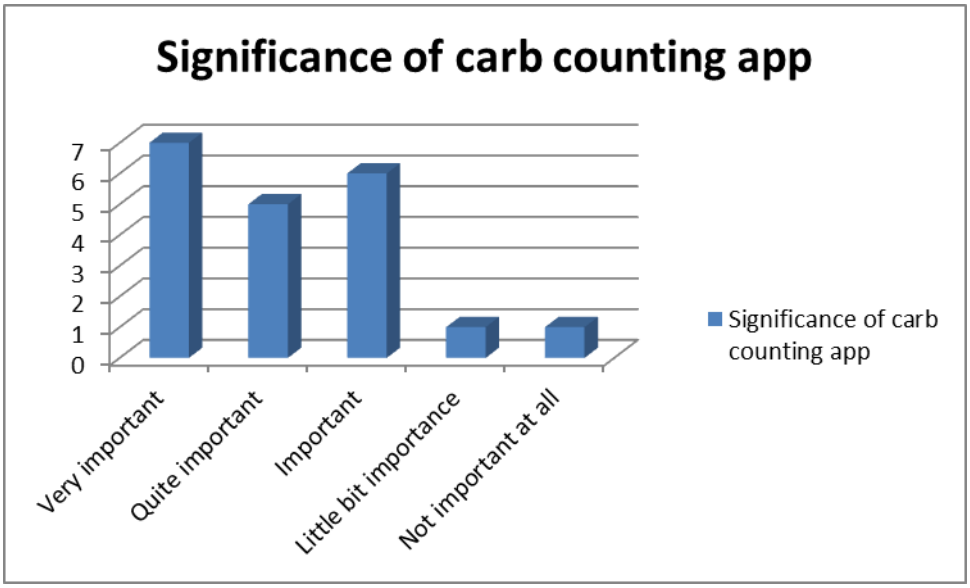

Figure 65. Significance of carbohydrate counting application (Korea)

7.2 Presentation about 'Carb counting'

This presentation was followed after the questionnaire. It includes an introduction about the researcher and answers the questions below.

- What are carbohydrates?
- Why is it important to intake carbohydrates?

- Where can we find carbohydrates?
- The influence of carbohydrates on blood glucose level
- Example pictures of food items which have nutrition fact table where we can find carbohydrate amount
- One example of common Norwegian/Korean meal

7.3 Presentation about application

'Smart carb' was introduced with a power point file. This presentation included the purpose of 'Smart Carb' application, the procedure of using the application, examples of screen shots by following step by step, required amount of carbohydrate per day or per meal and practice with some typical diet.

To give participants a better impression they practiced 'Smart Carb' application with supervision and to enhance the reality, real food items were used. Below are the food items which were used.

- Bread : 2 boller, 3 slices of bread
- Topping : 3 boiled eggs, 3 slices of white cheese, 2 slices of salami, 2 slice of ham (2 types)
- Vegetable : cucumber, tomatoes
- Fruits : 1 mandarin, 1 apple, 4 slices of orange, half kiwi, green grape, strawberry
- Drinks : milk, orange juice, 2 bottles of soda
- Equipment : 1 empty glass, scale

When the participants tried 'Smart Carb' application, they could choose the food items they would like to eat for their meal. They weighed each items with scale and registered the weights of food items into the application.

Because Korean food items are difficult to weigh, no real food item was used for the participants' practice. Serving portion was displayed for users' reference instead of weigh the food items. The Korean participants found the food items which they wished to eat in the application and checked the carbohydrate amounts in default portion size. Then they registered the food items. Figure 66 shows an example of Norwegian bread meal and Figure 67 shows an example of Korean meal.

Figure 66. An example of Norwegian meal

Figure 67. An example of Korean meal

7.4 Result of usability test[8]

After the participant tried to use 'Smart Carb' application, the sheet of usability test was distributed. The numbers in below tables show the numbers of people answered. However many people said they needed more time to use the application to answer those questions properly.

		Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	Norway					7
	Korea	2	4	6	6	2
2. I found the system unnecessarily complex	Norway	6	1			
	Korea	2	1	8	5	4
3. I thought the system was easy to use	Norway				1	6
	Korea	4	5	6	5	
4. I think that I would need the support of a technical person to be able to use this system	Norway	3		2	1	1
	Korea	3	2	5	1	9
5. I found the various functions in this system were well integrated	Norway				4	3
	Korea		2	7	1	10
6. I thought there was too much inconsistency in this system	Norway	4	2	1		
	Korea	7	3	8		2
7. I would imagine that most people would learn to use this system very quickly	Norway				2	5
	Korea		2	8	4	6
8. I found the system very cumbersome to use	Norway	6	1			
	Korea	2	3	7	6	2

[8] Appendix 2.

9. I felt very confident using the system

Norway			1	5	1
Korea	3	8	3	5	1

10. I needed to learn a lot of things before I could get going with this system

Norway	4	2			1
Korea	2	4	3	2	9

7.5 Verbal questions

To get the participants' opinion about the system, some questions were asked in this session. The questions are like below.

- The reason why do you want to use or don't want to use the application
- Which part in this system is the most or least complicated to use?
- Which part should be improved and how?
- Which part in this system is easiest or most difficult to use?
- For the functionality, which part should be improved?
- The reason why technical support is necessary or unnecessary?
- For which part in this system, you need the most (least) technical support?
- What do you think about 'Carbohydrate counting'?
- 'Carbohydrate counting' will be helpful for you or not?
- What do they think about 'Smart Carb' application?
- In which way, 'Carbohydrate counting' with smart phone will be helpful for you?
- Is 'Smart Carb' application helpful for you to learn how different food influences your blood glucose levels? In which ways?
- Which function in the application is the most useful for you?

7.6 Summary

This chapter describes how the test was conducted and presents the result of the test.

The answers about blood glucose level controlling in questionnaire shows the difference between control group (Norwegian participants) and non-control group (Korean participants). The need for tools to count carbohydrate amounts was found through the questionnaire as well.

This chapter illustrates how the presentations about carbohydrate and its counting were conducted in Norway and Korea. The reason why different parameters were used to register the amount of food items in the two systems for Norwegians and Korean were explained.

Lastly, this chapter presents the results from the usability test and describes the verbal questions that were conducted in the individual interviews.

Chapter 8

Discussion

All the major findings and the interpretation of findings is discussed in this chapter. Firstly the findings from questionnaire will be discussed. Then the findings from usability test will be presented. Lastly the findings from verbal questions and answers will be discussed.

8.1 Findings from questionnaire

8.1.1 General information

Norwegian participants were recruited from a focus meeting. However Korean participants were recruited randomly by asking outpatients who were in the hospital. Therefore the gender distribution is not same.

A same age criterion was used. The age of Norwegian focus group was between 40 and 80 years old and the same age criterion was adopted in the announcement to recruit participants in South Korea. There was one more participant who took part in this test however this person was outside of age criterion therefore the test result from this person was excluded.

The number of year since first diagnosed, whether they take insulin or tablet were also asked but no significant differences were detected.

8.1.2 Blood glucose control

There is significant difference between Norwegian and Korean participant about the questions regarding blood glucose level controlling. Because the focus group which the Norwegian participants are from had been involved in another project, all of them had used the 'Few touch application', a self-management tool for diabetics for more than 1 year. However none of the Korean participants had experience like that. For this reason Norwegian participants were more satisfied with their blood glucose level controlling than Korean participants. In addition most of the Norwegian participants answered that controlling blood glucose level was not difficult when most of the Korean participants

answered that controlling blood glucose level was difficult. The reason of these results expected that it is because of the difference of experience between Norwegian participants and Korean participants whether they used diabetes management application before or not.

It was revealed that most of the Norwegian participants measured their blood glucose level more than once a day. However there were 50% of Korean participants who measure their blood glucose level less frequently than once per week. The reason for this is guessed that Norwegian participants were in control while they were using 'Few touch application. Therefore they had measured blood glucose level more frequently than Korean participants. This result shows the advantage of using self-help tool for people with diabetes.

The time for measuring blood glucose level varied. Most of the participants said that they measured in the morning before a meal. However, fewer people measured their blood glucose level again in a certain period time of after meal. This result shows lack of effort to control blood glucose levels by observing the food they take.

8.1.3 Carbohydrate counting

No participant in Norway had experience of 'Carbohydrate counting'. However 20% of Korean participants had experience of doing carbohydrate counting. All the participants both in Norway and South Korea knew little or did not know about Carbohydrate counting. As can be seen on Table 11 in chapter 7, few people estimated their carbohydrate intake when they ate. 4 of the 7 in Norwegian participants and 12 of the 20 Korean participants had never estimated carb amount. This result shows their lack of awareness or knowledge about carbohydrate and its influence on blood glucose level. About the question, 'How much is it important to trace amount of carbohydrate?', the Norwegian participants admitted to its importance (28.57%: Quite important and 28.57%: Important). But 42.86% of them said that it is slightly important. However nevertheless many of Korean participants answered that tracing carb amount is important (30%: Very important, 20%: Quite important and 30%: Important), 10% of them said that tracing carb amount is not important at all. 10% people answered it is 'Slightly important'. This result can be interpreted that carb counting is regarded as a significant matter to manage their disease overall however there are also some people who does not regard it as an important matter. It can be understood that maybe because those people did not know about carb counting and its influence on blood glucose. The questionnaire is conducted before carb counting and its influence on blood glucose level were introduced after the questionnaire. Regarding the difficulty of estimating carb amount of the food they eat, most of the participants answered that it was difficult. The need of carb counting application is presented in Table 14 in chapter 7. Most participants answered that it was important to have that kind of application.

8.2. Findings from usability test

100% of Norwegian participants strongly agreed to use 'Smart Carb' application often however the answers from Korean participants were varied. None of Korean participants had used smart phone before. Lack of experience of smart phone made them to be afraid to dare to use the application. It is shown as well in the result of question number 2 in the usability test. Most of Norwegian participants strongly disagreed or disagreed that the system is unnecessarily complex, however many of the Korean participants (45%) strongly agreed or agreed that the system was unnecessarily complex. Because they did not have any experience of using that kind of smart phone application before.

Regarding ease of use of this application, it was accepted to the participants in the same way. All of the Norwegian participants thought the application easy to use, however only 25% of the Korean participants agreed that it is easy to use. 45% of the Korean participants said it is difficult to use because they did not have any experience of using smart phone.

Regarding the need of technical support, people who were confident to using technical stuff answered they didn't need technical support. However people who were not confident to using electronic devices (28.57% of Norwegian participants and 50% of Korean participant) answered that they did need technical support to be enable to use 'Smart Carb' application.

About the degree of integration of the application, 100% of the Norwegian participants said it is well integrated. And 55% of Korean participants also agreed that it is well integrated. However 35% of Korean participants answered that it is difficult for them to answer because they need more time to use the application. Regarding inconsistency, most of the participants disagree.

100% of Norwegian participants and 50% of Korean participants said most people would learn to use this application quickly. However 10% of Korean participants disagree that would be easy for most of people and 40% of Korean participant were neutral. The reason for this answer was also because they thought that it will take time for the people who did not have experience of using smart phone.

100% of the Norwegian participants disagreed that Smart Carb was cumbersome. However only 25% of the Korean participants disagreed and 40% of them agreed that it is cumbersome. The reason for this answer was they thought it could be irritate people who have busy life. The reason can be understood because Korean people have busier lives than Norwegian people. The average working hours in South Korea are also longer than in Norway and the trend changing faster in South Korea than in Norway.

Most of the Norwegian participants had confidence using the application however 55% of the Korean people did not have confidence using the application due to lack of experience using smart phones.

85.71% of the Norwegian participants disagreed that they needed to learn many things

before they use this application. However 55% of the Korean participants agree that they do need to learn many things before they start to use this application. They said first they need to learn how to use smart phone and then they need to learn how to use the application. Regarding the time period of learning the system, 1 week's training course was suggested by several participants.

None of the Korean participants had experience using smart phone. On the other hand all of the Norwegian participants had experience of using smart phone. The main reason why the result of SUS is quite different can be interpreted with this.

8.3. Findings from verbal interviews

The finding from verbal interviews can be summarized like below.

8.3.1 Norwegian patient group

- Carbohydrate counting

Overall opinion from the Norwegian participants about carbohydrate counting was positive. The comment includes "Carbohydrate counting is an interesting area.", "Carbohydrate counting is very useful because we can see food items' influence on blood glucose levels", "Carbohydrate counting is a key to make the blood glucose level down", "It's helpful for me to eat low carbohydrate food".

- Ease to use

All the Norwegian participants agreed that 'Smart Carb' is easy to use. Their comment about Smart Carb's usability was "It is not complicated at all.", "These is no problem. Everything is easy to use.", " I understand quite well the meanings in this program", etc.

- Consistency and integration

All the Norwegian participants were satisfied with 'Smart Carb' application's consistency and integration. They said, "The overall flow is easy." "The system provides a logical way to think." "Different parts in this system were well integrated." "It is easy to follow the steps".

- Need to have this kind of Program

All the Norwegian participants answered that they want to have the 'Smart Carb' application. 6 of them said they were looking for this kind of program. They expressed that they want to try 'Smart Carb' for a longer period of time to observe how their body react on the food items they eat. They argued that that would be helpful for them to decide which food items

they would eat.

- Most useful part

Most participants picked the function to check the carbohydrate amount would be the most useful for them. One said the last screen which shows the difference of blood glucose levels with food list would be the most useful.

8.3.2 Korean patient group

- Carbohydrate counting

With the exception of 2 people, the majority of the Korean participants said carbohydrate counting is helpful for their nutrition management and blood glucose control. The reason is that they can be aware of it when planning what to eat. However one participant doubted the effect of carbohydrate counting because it did not feel necessary. Another participant said the system is helpful but it might give stress.

- Ease to use

Because there was no one who had used smart phone before in Korean patient group, many of the participants felt the system was complex or difficult to use. However they guessed it would be easy to use if they had experience with smart phone before.

- Need to have this kind of program

Some participants appealed they want to use the system. They agreed that 'Smart Carb' would be useful in self-nutrition management. However more people did not want to use the system often because they were afraid of using it due to the lack of the experience with a smart phone.

- Consistency and integration

Nevertheless most of the participant agreed that the system was well integrated and had a strong consistency.

- Most useful part

Like the Norwegian participants, most of Korean participants agreed that the function to check carbohydrate amount would be the most useful for them. Some of them also picked the last screen that shows the difference of blood glucose levels with the food list. 5 participants said they preferred the function that shows the difference of blood glucose levels. 2 people liked the SMS receiving function.

8.3.3 Points to improve

Even though, the overall feedback about ‘Smart Carb’ was positive, some points to improve were found as well. It can be summarized like below.

- More time needed to learn the system

Most of the participants agreed that they need more time to learn how to use the system. The period they recommended varied from 30 minutes to 1 week.

- Easier way to weigh food

Three of Norwegian participants said people could not weigh the food items all the time. People can remember the weights after repeated usage, and register without a scale. This is good for people with an educational purpose. However for the long term, this process can irritate people. Easier ways to weigh such as auto recognition of photos should be researched further.

- Back button

There is no back button in ‘Smart Carb’ application so that participants wished to have it in case they change their plan of what to eat.

- Normal phone

Many of Korean participants wish to have ‘Smart Carb’ application in a normal phone as well because they don’t have it and cannot afford to buy it.

- Include food items for dinner meals

One Norwegian participant wish to have more food items for dinner meals, because for the person, dinner had the greatest influence on the blood glucose levels.

- Busy life schedule

Many of Korean participants worried if ‘Smart Carb’ can be used in their busy life schedule. For educational purposes, as my main assumption and plan for this thesis project, it would be ok. However for longer period of time, we may need to regard simpler way to count carbohydrate.

- Portion size

Only one standard portion size for each food item was adopted for Korean version. Korean participants wished to have various portion sizes so that they can choose.

8.4 Summary

This chapter discusses the result from the entire research.

Firstly the result from questionnaire is discussed. The result shows the importance of tracing carbohydrate amounts in diabetes nutrition management and stresses how difficult estimating carbohydrate is. It also shows high need for tools to aid with carbohydrate counting.

Later, this chapter discusses about the result of the usability test. The result of verbal interviews are analysed and discussed as well. Because the condition of participants in the two countries was not the same, the result of usability was different. The Norwegian participants were more disposed to use ‘Smart Carb’ application. However the degree of willingness among Korean participants with no experience of using smart phone and its application varied. Due to the limited time for this research, it was not possible to recruit subject groups in the same condition. Most of the participants regardless of country, agreed the consistency and integration of the system. The points to improve were discussed in this chapter as well.

Chapter 9

Concluding remarks and future work

9.1 Conclusion

The main research problem in this thesis project was to develop a mobile phone application which can help people with diabetes to make right choices in selecting food items for better nutrition management. The major challenge was minimizing the information displayed and finding a way to persuade the users to change their food habits. Smart Carb, a simple application was developed to solve this problem and tested by 27 Type 2 diabetics in Norway and South Korea. The Norwegian participants who had experience with the 'Few Touch application' expressed their strong willing to use this application. However the Korean participant who did not have experience with kind of application and the smart phone itself, were more sceptical or afraid of using this application. Nevertheless most of the participants agreed that it is important to track the amount of carbohydrate intake, and expressed that it is difficult to estimate the amount of carbohydrate. Therefore they wanted to have a tool to help them to estimate carbohydrate amounts. The impact or effectiveness of this system was positive to the participant, specially the Norwegian participants who had experience with mobile diabetes self-help tool.

The inferences regarding sub-questions which were claimed in chapter 1 are presented below.

Question 1: To improve self-nutrition management for people with diabetes, what kind of information should be included in the application?

Carbohydrate was chosen to be provided in the application. There are other nutrients which also influence blood glucose level for example fat. But carbohydrates are the main nutrient which affects blood glucose levels the most. Therefore only the amount of contained carbohydrate was decided to be displayed as nutrition information in 'Smart Carb' application.

Question 2: How can the food items be categorized in a simple way in order to find relevant information quickly?

In this research, only one category step was adopted to shorten the time to find food items.

Cultural difference, the characteristics of dishes in Norway and South Korea were considered to categorize food items. Norwegian food items were categorized by food type. However Korean food items were categorized by the way to cook. Advices from nutritionists both in Norway and South Korea were reflected in organizing the food categories.

Question 3: Which food items should be included in this application for the users to use this application in a practical way?

The target users are Norwegian and Korean therefore the most common and popular food items were selected from the credible sources in Norway and Korean to improve the practicability. Some food items without carbohydrate were also included so that the users can learn which food items do not have carbohydrate. The reason for this was because 'Smart Carb' was developed with educational purpose.

Question 4: How should this application be designed to have a user-friendly interface which can be used easily, naturally and unobtrusively in real life situations?

For user friendly interface, only short simple sentences are used. Also pictures of each food items are displaying each time the user select the food item. Big font is used for the amount of carbohydrate to catch the user's eye. Different colours are used to distinguish carbohydrate amount per 100g, carbohydrate amount of weighted food and total carbohydrate of several food items.

Question 5: How should this application motivate the users to persuade them to change their habits for better nutrition management?

Weighing food item makes the users enable to check and remember the contained carbohydrate amount of food item. Checking the difference of blood glucose level before and after meal and all the food items eaten, make the users think about which food items influenced their blood glucose levels. These series of procedure motivate the users to change their food habits.

9.2 Thesis contribution

First nutrition management application for people with diabetes in Norway and South Korea

This project is the first attempt to test a nutrition self-management mobile phone based application for people with diabetes in Norway and South Korea. The subjects' condition of nutrition management and the level of satisfaction were investigated also in these two countries before the application was introduced. The food items in the applications were selected and brought from credible sources in Norway and South Korea

Overview of perception about importance of nutrition self-management

Through the questionnaire, the importance of nutrition self-management was investigated. And the result from it shows an importance of perception about nutrition self-management both for Norwegian and Korean participants.

Teach yourself and improve your nutrition management

This application enables the user to learn food's influence on blood glucose level by providing carbohydrate information and summing up for several food items. Then let them change their food habits themselves. This is a new way for people with Type 2 diabetes to manage diet. And it is first android carb counting application in Norway and South Korea.

Simple but rich nutrition information

The nutrition information which is provided by this application is simple, because it only provides carbohydrate information. However compare to 'Few touch application', this application provides richer nutrition information, because the nutrition information, carbohydrate information is based on real food items which are found in our real life.

9.3 Future work

More food items

More food items are encouraged to be included. This thesis project was focused on the educational purpose of helping people with diabetes to check the food's influence on their blood glucose levels by themselves and encourage them to change their food habits. Therefore limited food items were included. However for the practical use, it would be much better if more items can be included.

Blood glucose checking automatically

In this application, the user should measure their blood glucose level by themselves before and after meal. However if it can be done automatically with a separate program and share the information with Smart Carb application or it is integrated into this system it would be much better to use and shorten the time to use this system.

History function

This system can save up to 10 items but does not provide a history function. A history function to compare a person's diet for each day, for example for 1 week or 1 month, is suggested to be included in 'Smart Carb' application.

Better way to measure food weight

Due to the educational purpose, the user of this system (not Korean version) should weigh food items. If there is a way to estimate the weight of the food item without scale like auto photo recognition, it is recommended to be integrated into this system.

Include activity measure function

There are other factors which can influence blood glucose level. Activity is a factor among them. The function of tracing activities is also encouraged to incorporate.

Integrated to few touch application

There has been feedback that some of the users of the 'Few touch application' were not satisfied with nutrition registration function of the system. Like some of Norwegian participants mentioned, if this Smart Carb can be incorporated into the 'Few touch application', it can be a more powerful self-help tool for people with diabetes which can provide rich information regarding nutrition management. Many of Norwegian participants wished 'Smart Carb' application could be integrated to 'Few Touch Application'.

Appendices

Appendix 1A: Questionnaire (Norwegian version)

Deltaker nummer :
23.05.2011

A. General

1. Alder

2. Kjønn

3. Hvor mange år har du hatt diabetes?

4. Bruker du insulin (sprøyter, penn) i din diabetesbehandling?
❒ Ja
❒ Nei

5. Bruker du tabletter i din diabetesbehandling?
❒ Ja (Hvilken type tabletter:_____)
❒ Nei

B. Blodsukkerkontroll

6. Er du fornøyd med blodsukkernivået ditt til daglig?
❒ Ja
❒ Nei

7. Synes du at det er vanskelig å kontrollere ditt blodsukkernivå?
❒ Ja(Hvorfor?_____)
❒ Nei

8. Hvor mange ganger per dag måler du ditt blodsukker?

9. Når på dagen måler du ditt blodsukker?

C. Karbohydrattelling

10. Har du prøvd karbohydrattelling?
❒ Ja
❒ Nei

11. Hvor godt kjenner du til karbohydrattelling?
❒ Kjenner godt til
❒ Kjenner litt til det
❒ kjenner ikke til

12. Planlegger du hvor mange karbohydrater du skal spise før måltider?
❒ Veldig ofte
❒ Ofte
❒ Av og til
❒ Sjelden
❒ Aldri

13. Hvor viktig er det for deg å følge med på hvor mye karbohydrater du spiser?
❒ Veldig viktig
❒ Ganske viktig
❒ Viktig
❒ Litt viktig
❒ Ikke viktig i det hele tatt

14. Er det vanskelig å vurdere hvor mye karbohydrater du spiser?
❒ Veldig vanskelig
❒ Ganske Vanskelig
❒ Vanskelig
❒ Litt vanskelig
❒ Ikke vanskelig i det hele tatt

15. Hvilken betydning tror du det vil ha for deg å ha et program som kunne hjelpe deg å telle karbohydrater?
❒ Veldig stor betydning
❒ Stor betyding
❒ Litt betydning
❒ Velig liten betydning
❒ Ingen betydning

Appendix 1B: Questionnaire (Korean version)

피험자 번호:

날짜: 2011. .

일반적인 사항

1. 나이

2. 성별

3. 최초로 당뇨병으로 진단받은지 얼마나 되었습니까?

4. 당뇨병 치료에 인슐린(주사기, 펜)을 사용하시는지요 ?

❒ 예

❒ 아니오

5. 당뇨병 치료에 약물을 복용하시는지요?

❒ 예(어떤 타입의 약물을 복용하시는지요?:_____)

❒ 아니오

혈당 조절

6. 매일 측정하시는 혈당 수치에 만족하시는지요?

❒ 예

❒ 아니오

7. 혈당 수치를 조절하는 것이 어렵다고 생각하시는지요?

❒ 예(이유:_____)

❒ 아니오

8. 하루에 혈당을 몇번이나 재시는지요?

9. 하루 중 언제 혈당을 재시는지요?

탄수화물양 계산

10. 드시는 음식의 탄수화물양을 계산해보신 적이 있으신지요?
❒ 예
❒ 아니오

11. 탄수화물양 계산에 대해 얼마나 잘 알고 계시는지요?
❒ 잘 알고 있다
❒ 조금 알고 있다
❒ 알지 못한다

12. 식사하시기 전에 탄수화물을 얼마나 섭취하실지 계획을 세우시는지요?
❒ 매우 자주
❒ 자주
❒ 때때로
❒ 가끔
❒ 전혀 안한다
13. 섭취하시는 탄수화물의 양을 추적하는 것을 얼마나 중요하게 여기시는지요?
❒ 매우 중요하다
❒ 꽤 중요하다
❒ 중요하다
❒ 조금 중요하다
❒ 전혀 중요하지 않다

14. 섭취하신 또는 섭취하실 탄수화물의 양을 짐작하는 것이 어려우신지요?
❒ 매우 어렵다
❒ 꽤 어렵다
❒ 어렵다
❒ 조금 어렵다
❒ 전혀 어렵지 않다

15. 탄수화물양 계산을 도와주는 프로그램을 가지는 것이 당신에게는 어떤 의미인지요?
❒ 매우 중요한 의미
❒ 꽤 중요한 의미
❒ 중요한 의미
❒ 조금 중요한 의미
❒ 전혀 중요하지 않은 의미

Appendix 2A: Interview guide (Norwegian version)

Karbohydratertelling og applikasjon

1. Hva synes du om Karbohydrattelling?
2. På hvilke måter tror du at Karbohydrattelling kan hjelpe deg?
3. Hva synes du om Karbohydrattelling med dette programmet?
4. På hvilke måter tror du at Karbohydrattelling med smartmobilen kan hjelpe deg?
5. Tror du dette programmet kan være til stor eller liten hjelp for deg for å lære mer om hvordan forskjellig mat påvirker blodsukret ditt?

Ja/Nei

6. På hvilke måter?
7. Hvilken del av dette programmet er mest nyttig for deg?

Takk skal du ha!

Appendix 2B : Interview guide(Korean version)

탄수화물양 계산과 어플리케이션

1. 탄수화물양 계산에 대해서 어떻게 생각하시는지요?

2. 탄수화물양 계산이 어떤 면에서 피험자님께 도움이 될 것이라고 생각하시는지요?

3. 제가 개발한 프로그램으로 하는 탄수화물양 계산에 대해서 어떻게 생각하시는지요?

4. 스마트 폰으로 하는 탄수화물양 계산이 어떤 면에서 피험자님께 도움이 될 것이라고 생각하시는지요?

5. 제가 개발한 이 프로그램이, 피험자님께서 서로 다른 음식이 어떻게 피험자님의 혈당 수치에 영향을 미치는지에 대해 배우는 데에, 작은 또는 큰 도움이 된다고 생각하시는지요?

6. 어떤 면에서 도움이 된다고 생각하시는지요?

7. 이 프로그램의 어떤 부분이 피험자님께 가장 유용하다고 생각하시는지요?

Appendix 3: First meeting with MD. Choi

Discuss about patients involved test in Korea

Seoul St. Mary's hospital, January 2011

Appendix 4: Meeting with nutritionist

Aker university hospital, April 2011

Appendix 5: Focus group meeting in Norway

Presentation about carbohydrate

Harstad hospital, May 2011

Appendix 6: Individual interviews in Norway

Presentation about 'Smart Carb' application

Harstad hospital, May 2011

Appendix 7: Individual interviews in South Korea

Usability test and verbal interviews

Seoul St. Mary's hospital, June 2011

References

1. The Universal Declaration of Human Rights [Internet]. The United Nations. 2010 [cited 2010 Dec 9];Available from: http://www.un.org/en/documents/udhr/#atop

2. Polly RK. Diabetes health beliefs, self-care behaviors, and glycemic control among older adults with non-insulin-dependent diabetes mellitus. The Diabetes Educator. 1992;18(4):321.

3. Toobert DJ, Hampson SE, Glasgow RE. The summary of diabetes self-care activities measure: results from 7 studies and a revised scale. Diabetes Care. 2000;23(7):943.

4. Anderson RM, Fitzgerald JT, Oh M. The relationship between diabetes-related attitudes and patients' self-reported adherence. The Diabetes Educator. 1993;19(4):287.

5. Sullivan ED, Joseph DH. Struggling with behavior changes: A special case for clients with diabetes. The Diabetes Educator. 1998;24(1):72.

6. Årsand E. The few touch digital diabetes diary: user-involved design of mobile self-help tools for peoplewith diabetes. 2009;

7. Ahlgren SS, Shultz JA, Massey LK, Hicks BC, Wysham C. Development of a Preliminary Diabetes Dietary Satisfaction and Outcomes Measure for Patients with Type 2 Diabetes. Quality of Life Research. 2004 May 1;13(4):819-832.

8. Nagelkerk J, Reick K, Meengs L. Perceived barriers and effective strategies to diabetes self-management. Journal of Advanced nursing. 2006;54(2):151-158.

9. Tatara N, Arsand E, Nilsen H, Hartvigsen G. A review of mobile terminal-based applications for self-management of patients with diabetes. In: eHealth, Telemedicine, and Social Medicine, 2009. eTELEMED'09. International Conference on. IEEE; 2009. p. 166-175.

10. Arsand E, Tatara N, Østengen G, Hartvigsen G. Mobile phone-based self-management tools for type 2 diabetes: the few touch application. J Diabetes Sci Technol. 2010 Mar;4(2):328-336.

11. Arsand E, Tufano JT, Ralston JD, Hjortdahl P. Designing mobile dietary management support technologies for people with diabetes. J Telemed Telecare. 2008;14(7):329-332.

12. Denning PJ, Comer DE, Gries D, Mulder MC, Tucker A, Turner AJ, et al. Computing as a

discipline. COMPUTER,. 1989;:63-70.

13. Diabetes mellitus - Wikipedia, the free encyclopedia [Internet]. Wikipedia. [cited 2010 Dec 11];Available from: http://en.wikipedia.org/wiki/Diabetes_mellitus

14. Your Guide to Diabetes: Type 1 and Type 2 [Internet]. [cited 2010 Dec 16];Available from: http://diabetes.niddk.nih.gov/dm/pubs/type1and2/what.htm#kind

15. Diabetes Types - Types of Diabetes - Type 1, Type 2, Gestational [Internet]. [cited 2010 Dec 16];Available from: http://www.diabetes.co.uk/diabetes-types.html

16. Australian Government Department of Health and Ageing. Types of Diabetes [Internet]. [cited 2010 Dec 16];Available from: http://www.healthinsite.gov.au/topics/Types_of_Diabetes

17. Wild S, Roglic G, Green A, Sicree R, King H. Global prevalence of diabetes. 2004;:1047.

18. Shaw JE, Sicree RA, Zimmet PZ. Global estimates of the prevalence of diabetes for 2010 and 2030. Diabetes research and clinical practice. 2010;87(1):4-14.

19. Jonsson B. Revealing the cost of Type II diabetes in Europe. Diabetologia. 2002;45(7):5-12.

20. Brandle M, Zhou H, Smith BRK, Marriott D, Burke R, Tabaei BP, et al. The direct medical cost of type 2 diabetes. Diabetes care. 2003;26(8):2300.

21. Brown JB, Pedula KL, Bakst AW. The progressive cost of complications in type 2 diabetes mellitus. Archives of internal medicine. 1999;159(16):1873.

22. Rubin RJ, Altman WM, Mendelson DN. Health care expenditures for people with diabetes mellitus, 1992. The Journal of clinical endocrinology and metabolism. 1994;78(4):809A.

23. Lorig KR, Holman HR. Self-management education: history, definition, outcomes, and mechanisms. Annals of Behavioral Medicine. 2003;26(1):1-7.

24. LeFort SM, Gray-Donald K, Rowat KM, Jeans ME. Randomized controlled trial of a community-based psychoeducation program for the self-management of chronic pain. Pain. 1998;74(2-3):297-306.

25. Bodenheimer T, Lorig K, Holman H, Grumbach K. Patient self-management of chronic disease in primary care. JAMA: the journal of the American Medical Association. 2002;288(19):2469.

26. Barlow J, Wright C, Sheasby J, Turner A, Hainsworth J. Self-management approaches for people with chronic conditions: a review. Patient Education and Counseling. 2002;48(2):177-187.

27. Berner ES. Clinical decision support systems: theory and practice. Springer Verlag; 1999.

28. Verhoeven AA, Boerma EJ, Meyboom-de Jong B. Use of information sources by family physicians: a literature survey. Bulletin of the Medical Library Association. 1995;83(1):85.

29. McDonald CJ. Protocol-based computer reminders, the quality of care and the non-perfectability of man. The New England journal of medicine. 1976;295(24):1351.

30. McDonald CJ, Wilson GA, McCabe GP. Physician response to computer reminders. JAMA: The Journal of the American Medical Association. 1980;244(14):1579.

31. Tierney WM, Hui SL, McDonald CJ. Delayed feedback of physician performance versus immediate reminders to perform preventive care: effects on physician compliance. Medical Care. 1986;24(8):659-666.

32. Tierney WM, McDonald CJ, Martin DK, Rogers MP. Computerized display of past test results. Effect on outpatient testing. Annals of internal medicine. 1987;107(4):569.

33. McDonald CJ, Tierney WM. Computer-stored medical records. JAMA: The Journal of the American Medical Association. 1988;259(23):3433.

34. Tierney WM, McDonald CJ, Hui SL, Martin DK. Computer predictions of abnormal test results. JAMA: The Journal of the American Medical Association. 1988;259(8):1194.

35. Farmer A, Gibson O, Hayton P, Bryden K, Dudley C, Neil A, et al. A real-time, mobile phone-based telemedicine system to support young adults with type 1 diabetes. Inform Prim Care. 2005;13(3):171-177.

36. Park K-S, Kim N-J, Hong J-H, Park M-S, Cha E-J, Lee T-S. PDA based Point-of-care Personal Diabetes Management System. Conf Proc IEEE Eng Med Biol Soc. 2005;4:3749-3752.

37. Tsang MW, Mok M, Kam G, Jung M, Tang A, Chan U, et al. Improvement in diabetes control with a monitoring system based on a hand-held, touch-screen electronic diary. J Telemed Telecare. 2001;7(1):47-50.

38. Fukuo W, Yoshiuchi K, Ohashi K, Togashi H, Sekine R, Kikuchi H, et al. Development of a hand-held personal digital assistant-based food diary with food photographs for Japanese subjects. J Am Diet Assoc. 2009 Jul;109(7):1232-1236.

39. Deshazo J, Harris L, Turner A, Pratt W. Designing and remotely testing mobile diabetes video games. J Telemed Telecare [Internet]. 2010 Aug 2 [cited 2010 Sep 13];Available from: http://www.ncbi.nlm.nih.gov/pubmed/20679406

40. Tani S, Marukami T, Matsuda A, Shindo A, Takemoto K, Inada H. Development of a health management support system for patients with diabetes mellitus at home. J Med Syst. 2010 Jun;34(3):223-228.

41. Mougiakakou SG, Kouris I, Iliopoulou D, Vazeou A, Koutsouris D. Mobile technology to empower people with Diabetes Mellitus: Design and development of a mobile application [Internet]. In: Information Technology and Applications in Biomedicine, 2009. ITAB 2009. 9th International Conference on. 2009 [cited 2010 Sep 14]. p. 1-4.Available from: 10.1109/ITAB.2009.5394344

42. Shroff G, Smailagic A, Siewiorek DP. Wearable context-aware food recognition for calorie monitoring [Internet]. In: Wearable Computers, 2008. ISWC 2008. 12th IEEE International Symposium on. 2008 [cited 2010 Sep 14]. p. 119-120.Available from: 10.1109/ISWC.2008.4911602

43. Forjuoh SN, Reis MD, Couchman GR, Ory MG. Improving diabetes self-care with a PDA in ambulatory care. Telemed J E Health. 2008 Apr;14(3):273-279.

44. Ma Y, Olendzki BC, Chiriboga D, Rosal M, Sinagra E, Crawford S, et al. PDA-assisted low glycemic index dietary intervention for type II diabetes: a pilot study. Eur J Clin Nutr. 2006 Oct;60(10):1235-1243.

45. Sevick MA, Zickmund S, Korytkowski M, Piraino B, Sereika S, Mihalko S, et al. Design, feasibility, and acceptability of an intervention using personal digital assistant-based self-monitoring in managing type 2 diabetes. Contemp Clin Trials. 2008 May;29(3):396-409.

46. Sevick MA, Stone RA, Zickmund S, Wang Y, Korytkowski M, Burke LE. Factors associated with probability of personal digital assistant-based dietary self-monitoring in those with type 2 diabetes. J Behav Med. 2010 Aug;33(4):315-325.

47. Claudi T. Nasjonale faglige retningslinjer: Diabetes—Forebygging, diagnostikk og behandling [National Professional Guidelines for Prevention, Diagnostics and Treatment of Diabetes]. Oslo: Helsedirektoratet. 2009;

48. Korean nutrition Society, Korean ministry of Health and Welfare, Korea Food and Drug Administration. Dietary Reference Intakes for Koreans [Internet]. The Korean Nutrition Society; 2010 [cited 2011 Jul 18]. Available from: http://www.kns.or.kr/

49. Grønnerud TL, Dahl-Jørgensen K. Karbohydrater og insulin - Tilpass insulin til maten du spiser. Novo Nordisk Scandinavia AS; 2009.

50. Seung Suk Lee. Diabetes I control. Woodumji Ltd;

51. Johnson MA. Carbohydrate Counting for People With Type 2 Diabetes. Diabetes Spectrum. 2000;13(3):149.

52. Nuttal FQ. Carbohydrate and dietary management of clients with insulin-requiring diabetes. Diabetes Care. 1993;16:1039-42.

53. Nuttall FQ, Gannon MC. Plasma glucose and insulin response to macronutrients in nondiabetic and NIDDM subjects. Diabetes Care. 1991;14(9):824.

54. Dinneen S, Gerich J, Rizza R. Carbohydrate metabolism in non-insulin-dependent diabetes mellitus. The New England journal of medicine. 1992;327(10):707.

55. Franz MJ, Bantle JP, Beebe CA, Brunzell JD, Chiasson J-L, Garg A, et al. Evidence-Based Nutrition Principles and Recommendations for the Treatment and Prevention of Diabetes and Related Complications. Diabetes Care. 2002 Jan 1;25(1):148 -198.

56. Gannon MC, Nuttall FQ, Westphal SA, Fang S, Ercan-Fang N. Acute metabolic response to high-carbohydrate, high-starch meals compared with moderate-carbohydrate, low-starch meals in subjects with type 2 diabetes. Diabetes Care. 1998;21(10):1619.

57. Wolever T, Bolognesi C. Prediction of glucose and insulin responses of normal subjects after consuming mixed meals varying in energy, protein, fat, carbohydrate and glycemic index. The Journal of nutrition. 1996;126(11):2807.

58. Gillespie SJ, Kulkarni KD, Daly AE. Using carbohydrate counting in diabetes clinical practice. Journal of the American Dietetic association. 1998;98(8):897-905.

59. Anderson EJ, Richardson M, Castle G, Cercone S, Delahanty L, Lyon R, et al. Nutrition interventions for intensive therapy in the Diabetes Control and Complications Trial. The DCCT Research Group. Journal of the american dietetic association. 1993;93(7):768.

60. Gregory RP, Davis DL. Use of carbohydrate counting for meal planning in type I diabetes. The Diabetes Educator. 1994;20(5):406.

61. Bruttomesso D, Pianta A, Crazzolara D, Capparotto C, Dainese E, Zurlo C, et al. Teaching and training programme on carbohydrate counting in Type 1 diabetic patients. Diabetes, nutrition & metabolism. 2001;14(5):259-267.

62. Kawamura T. The importance of carbohydrate counting in the treatment of children with diabetes. Pediatric Diabetes. 2007;8:57-62.

63. Brooke J. SUS-A quick and dirty usability scale. Usability evaluation in industry. 1996;:189-194.

64. Keshavjee K, Lawson ML, Malloy M, Hubbard S, Grass M. Technology failure analysis: Understanding why a diabetes management tool developed for a personal digital assistant (PDA) didn't work in a randomized control trial. In: AMIA Annual Symposium Proceedings. American Medical Informatics Association; 2003. p. 889.

65. Firtman M. Programming the Mobile Web. 1st ed. O'Reilly Media; 2010.

66. Tidwell J. Designing Interfaces, Patterns for Effective Interaction Design, pdf. 2010;

67. Papert SA. Mindstorms: Children, Computers, And Powerful Ideas. 2nd ed. Basic Books; 1993.

68. Maloney J, Resnick M, Rusk N, Silverman B, Eastmond E. The scratch programming language and environment. ACM Transactions on Computing Education (TOCE). 2010;10(4):16.

69. Resnick M, Maloney J, Monroy-Hernández A, Rusk N, Eastmond E, Brennan K, et al. Scratch: programming for all. Communications of the ACM. 2009;52(11):60-67.

70. Scratch MIT. Imagine, program, share. 2010;