Software Development for Managing Nutrition Intake for Type II Diabetes Mellitus

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***Abstract*—In this paper, we present the development and use of a nutrition assessment software namely Nutritracs for Type II Diabetes Mellitus (T2DM). We conducted a case study in India to understand how diet counselling impacts upon Type II Diabetes Mellitus (T2DM) management. We also highlight practical challenges in conducting such studies in developing countries and how we have addressed them, and the promising outcome in T2DM management - reduced the dependency on insulin as a management tool.**

I. Introduction

Diabetes Mellitus is a chronic hereditary disease characterised by a lack of endogenous insulin and resulting in hyperglycaemia and the excretion of excess glucose in urine. Severe untreated diabetes, of which hyperglycaemia is just one aspect of metabolic derangement, can lead to both macro and microvascular complications. A relatively simple and non-invasive method of preventing these complications is to recognise the impact of diet on insulin production and maintenance. Therefore, people with diabetes mellitus need help in planning and accepting a daily diet which contains the appropriate amounts of carbohydrates, protein, fat and fibre, together with adequate amounts of vitamins and minerals [1]. Diet generally has a great impact in the management of T2DM [2].

The incidence of T2DM can affect any person of any age, not limited to particular age group(s). Indians generally are at a higher risk of developing T2DM, due to their racial background and increased genetic weakness towards the development of diabetes. According to prior a study, about a third of people living with T2DM in India have family members with diabetes, and a result of this, there is a 40% risk of developing diabetes due to hereditary issues [3].

According to Ramachandran [4]], important risk factors that increases a person's chances of developing diabetes include: obesity, central adiposity (increased waist to hip ratio), age, family history of diabetes, and lifestyle changes due to urbanization. The ability to reverse or modify a risk factor results in two different subtypes of classification non-modifiable and modifiable risk factors, otherwise known as host risk factors and reversible risk factors. When considering T2DM, there are four main non-modifiable risk factors age, gender, race and family history. These factors cannot be reversed because they are inherently linked to each person diagnosed with the disease and cannot be altered in any way. The risk factors that can be controlled and managed are dietary habits, physical activity, life style changes and the combination of these three.

In order for dieticians to manage diabetes in individuals, prolonged dietary treatment of diabetes is the very baseline of all forms of T2DM treatment [5]. An important cornerstone in the management of T2DM, and achievement of the aim of dietary treatment is a well-designed meal, taking into account the total caloric content and nature of diet [6], [7]. Diet, combined with oral hypoglycaemic agents, is the next tier in T2DM treatment. There are several classes of orally administered anti-diabetic agents available for use in patients with T2DM. It can be difficult to manage dietary intake in conjunction with medication and individual requirements for people with T2DM. Therefore, a software tool, in conjunction with dieticians would enable better management of dietary records and then arriving at a calorie calculator to suit their individual requirements.

Despite a number of Diabetes Mellitus management software tools are already available [8], [9], [10], [11], healthcare professionals in India and other developing countries still struggle to achieve health targets without the adjunct therapy of diet coaching or counselling. In this study, we developed and deployed a software tool that helps to keep track of nutrition requirements of Indians for T2DM. We also conducted the experiments to show how this software tool helped individuals to monitor their nutrition intake, and consequently, how it could help these individuals to manage their T2DM.

II. Software for Diabetics Management

A. Requirements Specification

The software application developed in this study is a web-based application, namely Nutritracs. The users of Nutritracs are general public with T2DM. We have a very careful consideration of what information needed to be captured, how it would be converted into a software field, the calculations required in computing various nutritional values, and so forth in order to identify the requirement specification because of each individual was different in their personality, eating habits as well as their level of diabetes. The software requirement specifications were extracted from three specific sources suggestions made by experts in the literature, participants on their

requirements, and physicians on the calculation of various values used in the determination of diabetes severity.

1) Requirements from the literature: Requirment specification was an essential component of software development. The literature was very helpful in understanding the basic information that needed capture. For example, the American Diabetes Associations guidelines provided recommendations on medical nutrition information. However, this information is not very suitable for Indians as their eating habits and diet are significantly different to a Western Caucasian population. While literature suggests monitoring daily exercise activities, there is limited information as to how these can be converted into a meaningful unit of measure, and how to correlate the same with food consumption. Experts suggest that we should encourage and allow patients to draw their own conclusions about adopting healthy lifestyles, but there is no clear way of articulating this with food consumed. They also suggest that family history should be captured, but codification of the same is a challenge. Similarly, as Indian food is varied in terms of quantity and choice, codification of the food intake is a challenge. We extracted salient aspects from the literature as to arrive at a minimal set of specification so that these can be coded into a software routine.

2) Participants' requirements: Participants expressed that they would like to have a software that is easy to use in terms of navigation, easy to understand in terms of nutrition consumption, and easy to enter data. The participant groups were diverse and one of the important considerations given to the software development was education, as the diagnosis of T2DM warrants self-education so that individuals can be empowered with their decision making. As food habits varied among people, it was essential to exactly understand how people eat in terms of frequency, quantity and type of food materials used to provide an accurate estimation of nutrition averages. These required in-depth interview to understand personal traits, and then convert these into a proper software specification. The inter-disciplinary mix of nutrition and IT was a key factor in arriving at the right specification, and the interview data was very helpful in extracting key information manually. A software text analysis tool (NVivo) was also used in extracting key information and collating required information under thematic concepts, so that these can be used at the time of requirement specification, development, and functional verification.

3) Physicians's requirements: Physicians use a different approach as they use predefined forms to capture information. The form consists of two aspects the clinical aspects and the nutritional aspects. While they capture an overarching view, details are not fully captured, and these details seldom enter the databases entirely. Our discussions with the physicians helped to understand what they are looking for in a T2DM patient and how this can be easily captured using a data entry system. While the blood results are accurate, other measures may not be accurate and these were estimated to a level that is sufficient to diagnose and manage a T2DM patient. Similarly, calculation routines of blood sugar calculations also followed different standards, and these needed to be normalised.

B. System Design

The three approaches discussed above helped us to develop software requirements specification led to the system design and development of software, Nutritracs application. Key considerations in designing and developing the software included:

1 Accommodating individual preferences to enter their dietary intake;
2 Using a simple drop-down box approach so as to avoid data entry mistakes;
3 Conversion of various Indian food items in a codified form so that value calculation could be standardised;
4 Standard base calculation for calorie calculation and provision for in-built calculation based on standard entries;
5 Provision for easy diet recalls so that individuals can compare their diet and blood sugar variations, thus empowering them to manage their food habits;
6 Consolidated diet recall to the dietician so that this can be used as a guide while providing counselling;
7 Decomposition of food items to extract other values, such as protein and carbohydrate breakdowns, based on standard calculators as recommended by the Indian Council for Medical Research; and
8 A server based system so that users can have access to the data from anywhere (this approach was followed as many of the clients were frequent travellers).

The technical design considerations included web links and their functional elements, user interactions with the system and modules, administration module for the dietician to control various health related behaviours from the data input, and providing a flexible way of data handling throughout the system. The design was further enhanced by a asynchronous communication protocol for data input, with report generation algorithms running as soon as an entry is made, and consolidated feedback given to users based on their data entry.

C. System Architecture and Development

The technical platform was based on the web based pubic domain system, fundamentally supported by a web based communication portal with a database interface through Oracle. The figure 1 shows the system architecture. The three level architecture assembled was for the reason of optimization at the hardware and software level, by dividing functionality between the servers: application server and the database server. The system was developed in such a way that access was facilitated by a web browser and needs no other application to be installed on the client machines. The system has an open architecture enabling modifications to accommodate future technology development as well as up-scaling. A major consideration in the system development is end users needing access to their data easily, and for the dieticians administering the applications remotely, either from their home or from hospitals. This enabled a multi-tiered system with a content layer, data tracking layer, service sequencing engines, content management service and service delivery modules developed

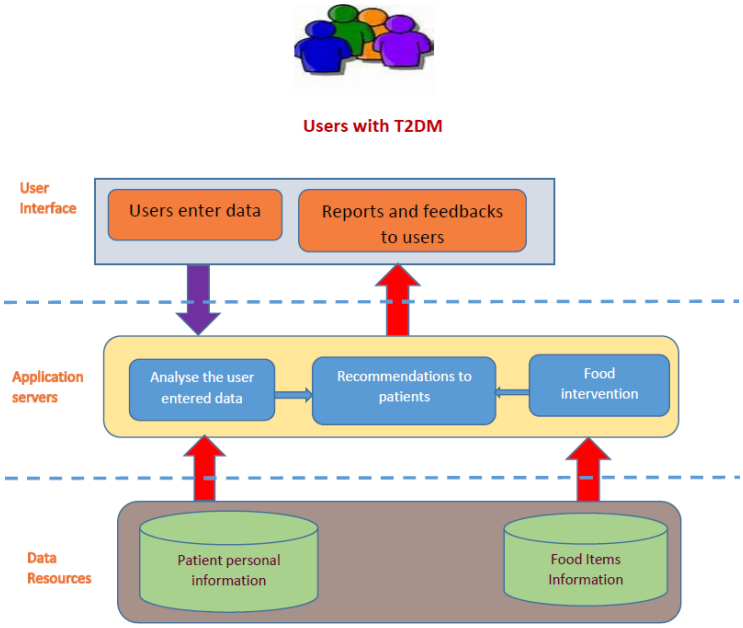

Fig. 1. Architecture of web-based system - Nutritracs

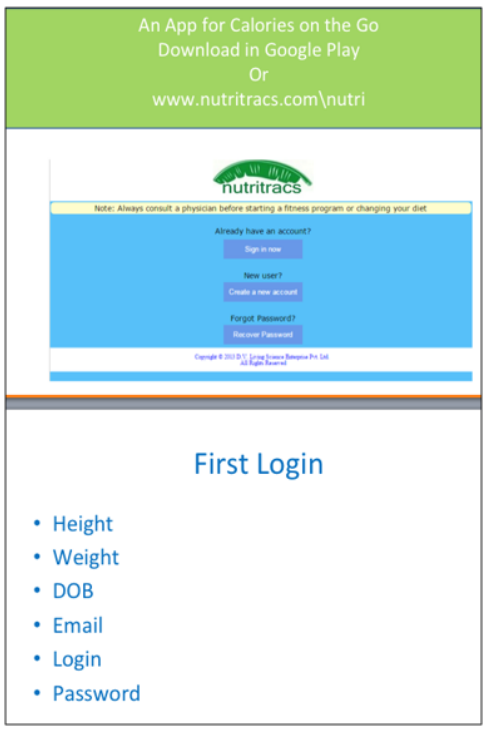

Fig. 2. Start-up page

and layered. These components formed the basis for the architecture. These architecture elements were supported by a Java based web application server, enterprise Java Beans, JDBC, Java Servlets, JSPs, XML and tested on an Oracle platform.

The user interface provides the functionality for interaction and communication between users and systems. The application servers obtain the users entered data via user interface and analyse these data. These include anthropometric measurements by using the standard formula shown in Eq. 1.

$$BMI = Weight(Kg)/Height(m^2) \quad (1)$$

The following biochemical parameters also were calculated

1 Serum LDL cholesterol was calculated using a formula as suggested by professional bodies
2 Serum VLDL cholesterol
3 Serum total cholesterol: HDL cholesterol ratio
4 Serum triglycerides: HDL cholesterol ratio

The patient personal information are collected and stored in the patient personal profile database. As these details varied between individuals, it was agreed by the research team that a qualitative approach would be suitable, and an interview schedule was used for this purpose. An interview schedule was prepared to elicit information from the subjects regarding age, family history of diabetes, occupation, socio-economic status, alcohol consumption and smoking, physical activity as well as information about their dietary pattern. The investigator interviewed each subject individually and the response was immediately recorded on the schedule. The dietician involved with our study was instrumental in preparing the interview schedule as she was most qualified to understand the dietary requirements. The academic team helped to structure the interview, and helped the dietician to conduct the interview, so that the details of the interview could be stored in the database and used by the system for data analysis and recommendations. The blood pressure levels of all the subjects were collected at different periods using blood tests and stored in patient personal profile database. Institutional ethics committee approved this proposed study, and written informed consent was obtained from each one of the subjects who participated in this study. The information of food items are stored in Food items information database.

III. SYSTEM EVALUATION AND DISCUSSONS

A. Experiments

The primary objective of the study was to determine the combined effect of periodical intensive counselling on diet using a software tool on T2DM patients, as well as on a diet and exercise combination program for a period of six month. A group of 500 people have participated to test the application at a particular time. Links were sent to college students. dieticians, Clients, People in the Information Technology sector, family and friends who logged in at the same time and testing was conducted. Screen shots and images of the application are shown in Figure 2 to 6.

B. Outcomes and Finding

The participation of the subjects in diet counselling was found to be very satisfying. Counselling was provided for the subjects and their caregiver/family during their visits to the referral centre. The software provided summary data and this helped the dieticians to assess the level of food intake, and the influences of food on blood sugar level during

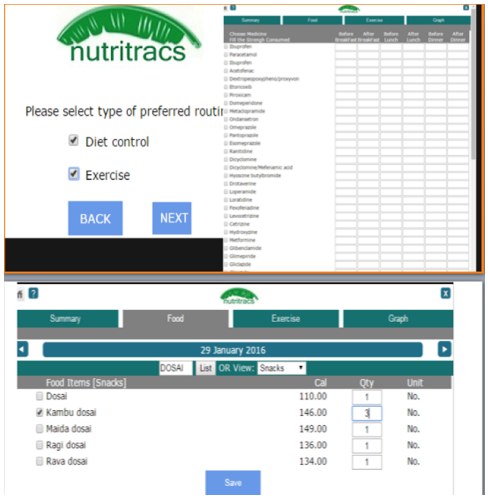

Fig. 3. Data entry page

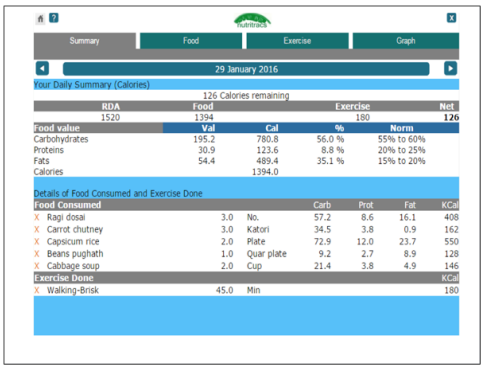

Fig. 4. Summary page

Fig. 5. Exercise details page

Fig. 6. Overall performance graph

assessments. Further, home visits, with prior appointment were organized to provide diet counselling to subjects who could not attend counselling sessions due to some valid reasons, and the software entry by users was found to be very useful in providing diet counselling. Spouses of most of the subjects were actively involved in the counselling sessions, with some even seeking counselling over the telephone for the sessions missed.

Feedback from subjects indicated that adherence to the diet prescribed was most difficult during festivals and special occasions. While this knowledge was already available, the granular details were provided by the software and this helped individuals to see where diet intake was not working so that adjustments were made to the diet, both in terms of quantity and frequency. During festival days, preparation and consumption of sweets and fried snacks are an essential part of the traditional celebrations and using the software, subjects were encouraged to enjoy the celebrations with low fat snacks and sweets prepared with artificial sweeteners, as the calorie and other nutrient information projects in the application helped individuals to understand the impact of diet.

Surprisingly, this study found that the average consumption of vegetables for a family of four members was only about 100 grams per day. Subjects preferred consuming raw vegetables with yoghurt rather than eating them as a plain salad. Subjects also had a lot of prejudices regarding fruit and vegetable consumption. Gourd vegetables and citrus fruits were avoided during rainy season as they were believed to be cold-inducing foods. Many of the subjects did not consume any fruit as they believed the same were not permitted for subjects with diabetes. The software produced evidence to dispel these myths, and it was possible to improve upon the lack of knowledge amongst people using the software.

It was possible to infer from the software data that the consumption of vegetables was further reduced in the diet of non-vegetarians as vegetable dishes were not usually included in non-vegetarian meals. Further, the average quantity of non-vegetarian food procured was more than the quantity of vegetables usually procured. Vegetarian dishes were usually consumed for one meal, whereas non-vegetarian dishes, if prepared, were carried over for two to three meals.

The biggest challenge in diet counselling, therefore, was to encourage increased intake of vegetables and to clear misconceptions about the inclusion of fruit in the diet of subjects with T2DM. Users who used the software and diet counselling were encouraged to increase their vegetable intake and include green leafy vegetables regularly in their diets. They were also advised to include fruits in prescribed amounts in their daily diet. Non-vegetarians were encouraged to include vegetable dishes along with the non-vegetarian dishes.

C. Contributions of Nutritracs

As a result of the software use, at the end of the trial period (six months), this study found that users who received periodic, intensive counselling on diet and exercise followed the dietary principles more carefully. These subjects were also more

enthusiastic and involved in the counselling sessions, even telephoning the counsellor between sessions for clarifications, as they were able to see the impact of the diet on their sugar levels and the positive changes in their diabetes management.

Further, when we assessed the combined effect of the software and diet counselling, we noticed that only a small percentage of the subjects experienced symptoms like giddiness, tiredness and weakness, which are indicative of poorly controlled diabetes. The biochemical profile of the subjects was monitored using tests for kidney function (microalbuminuria and serum hemoglobin) and SGOT and SGPT for liver function. Foot sensitivity and eye tests were also done at regular intervals to check for microvascular complications. These formed part of the software application so that data can be maintained for physicians diagnostic purposes.

Results indicated that subjects receiving periodic intensive diet counselling did not show any symptoms of progression to diabetic complications. None of the subjects followed up during the study had progressed to taking insulin to manage their condition. This follow-up was made possible because the software application tagged all details entered and both physicians and dieticians were able to see a unified view.

D. Nutritracs Software Development Challenges

The software development was a challenge, as the software needs to include a very large inventory of possible food items, for example over 3000 items needed conversion, and then apportion the same to quantity eaten. For this, we used the guidelines provided by the National Institute of Nutrition Guidelines and Indian Council of Medical Research Guidelines. These two guidelines are very specific to various Indian populations, and provide excellent break-up of various nutrition levels required for people of different age groups. This was used as a base in arriving at a diet and nutrition calculation.

The software was developed by a team of people lead by the dietician involved with our study. There was a perception among other dieticians that the software would replace the role of a dietician. Many seminars were provided to eliminate this apprehension, and challenges faced included making hospitals realise the need of such a software to make the dieticians role well-supported, and therefore less challenging. The greatest challenge was in arriving at standardisations in recipe calculations. Many senior dieticians in India were not computer savvy, and did not understand the importance of the software in tracking dietary patterns and habits in individual T2DM patients. This was overcome by providing training on the software as part of the graduation course for people to understand the importance of using the software, and resulted in many upcoming dieticians prepared to trial the software.

In terms of standardisation, Indian nutritive values of Indian foods were in a text book format, and these had to be digitized at the start of the project. When the tables from the text were used, we identified certain errors, and the same were communicated to the concerned authorities, and rectified. This also resulted in a web portal creation for standardised values, and these were now drawn into the software calculations to maintain currency and accuracy. This also helped to maintain scalability of the software. As we progressed in the software development, users wanted smartphone based interfaces, and the same was provided as an app in 2015.

IV. Conclusion

We have developed and deployed the Nutritracs - a web-base software tool that helps individuals and dieticians to monitor nutrition intake and manage T2DM. Currently about 200 diabetic patients in Chennai, India use the Nutritracs application. It is fund that Nutritracs helps these patients to keep their diabetic levels under control. The diet recall and other data help the dieticians to track progress as well as to provide consultation. Recently, an Android version was also created and basic interface using a mobile smartphone is provided to people who are on the move. Further, many more food items are also being added. In 2014-15, we also trialled the application with School children as well as college students in Chennai to assess the nutritional intake, especially in assessing the Recommended Dietary Allowance as specified by the Indian Council for Medical Research. This helped us to inform parents of children as to healthy eating habits so that school children and college girls can sustain their day with sufficient nutrition.

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