EDUCATIONAL SIMULATORS - COMPLIANCE WITH THE REQUIREMENTS OF DIABETES PATIENTS AND DIABETES THERAPY GUIDELINES

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Abstract: This paper presents renewed approach to the computer-aided diabetes educations introducing GIGISim (Glucose-Insulin and Glycemic Index Web Simulator) e-learning tool. Together with our system, selected solutions were summarized and their functionality compliance with diabetes therapy requirements checked. The analysis of diabetes patients needs has been established through a series of intermediate research surveys and literature studies. The software implementation of newly proposed innovations is presented together with effectiveness and suitability rate of a system, prior to the identified requirements.

1 INTRODUCTION

The overall goal of computer-aided diabetes education is to help individuals with diabetes mellitus gain the necessary knowledge about physiological processes, control dietetic habits and offer support needed on daily-basis. Rules presented below provide guidance for architects of this type of telemedicine systems, determining a basic functionality, which is to:

- improve or maintain the quality of life for people with diabetes,
- assist decision-making enhancing the patient's personal sense of control,
- help maintaining blood glucose and cholesterol levels as near-normal as possible,
- advice on insulin and medicaments doses,
- highlight diabetes-related complications symptoms,
- assess the individual's diet basing on nutrient requirements,
- educate on physiological processes and human carbohydrate metabolism.

Proper diet assessment is especially important as it influences the insulin and glucose response in time. Patients treated with insulin should adapt insulin type (long lasting, short lasting) to the pattern of their blood glucose response, while other patients should consult their diet to modify eating habits, loose weight or improve the body's sensitivity to insulin. As the diet plays an integral role in the therapy and as the dietetic guidelines have changed recently and new strategies have been developed for people with diabetes, new functionality must be thus implemented in the dedicated software.

Our research on nutritional management of diabetes follows the principles of Canadian (CDA, 1999) and the American Diabetes Association which will be fully presented in Chapter 2. Chapter 3 outlines main guidelines for diabetes-advisory systems, while chapter 4 presents the existing, diabetes dedicated educational tools with their innovations. Section 5 describes the GIGISim tool main functionality, providing detailed information on the application implementation and newly added features, with the possible effects on the therapy, conclusion and comments also detailed in Chapter 6.

2 NEW NUTRITIONAL GUIDELINES FOR DIABETES

Despite the importance of healthy diet in diabetes mellitus therapy, patients often neglect nutrition recommendations and increasing role of the Glycemic Index (GI) - the exact effect of GI on daily glucose variation is difficult to identify without dedicated methods. The Glycemic Index is a scale that ranks carbohydrate-rich foods by how much

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they raise blood glucose levels compared to glucose. Lowering the total GI of the diet may improve blood glucose control without raising serum triglycerides, reduce weight and normalize appetite which was proved for non-diabetes, type I and type II diabetes (T.M.S. Wolever, 1992; Frost G. Wilding, 1994).

Although diabetes canters and associations recommend GI as the important diet factor (Jenkins D.J, 2002; Ludwig DS 2002) and encourage considering GI among other dietetic rules, patient's rarely take it into account when preparing their meals. What is event more dangerous, but unfortunately very common according to our surveys, patients often ignore the importance of basic nutritional meal assessment, despite the necessity of the properly balanced diet in diabetes therapy. Calculations of fats, proteins, carbohydrates and calories are long and tedious and if the glycemic index should be included, as the additional nutrition factor, the process itself becomes even more complicated.

Although the glycemic index is a numerical value, available for nearly every food product and can be easily found in nutrition tables together with fats, proteins, carbohydrates and calories estimations it may be difficult to imagine and understand how exactly GI affects blood glucose variations. This is why in our previous papers we introduced a new web tool: GIGISim which is designed to educate patients on the GI impact on their diet and therapy. Our system visualizes the postprandial glucose profiles correlated to user's diet and improves patient's glycemic control which was proved in clinical research. The presented examples and research outlined advantages of the visualization method over numeric value estimation of a meal. The blood glucose variation graphic simulation used in GIGISim is far more meaningful and educative than figures and calculations.

In this paper we demonstrate the usefulness of GIGISim, emphasize the educational role of this internet tool and prove whether it satisfies the requirements of the prospective diabetes users, pointed in Chapter 1 and following Chapter.

3 DIABETES THERAPY RECOMMENDATIONS AND PATIENTS' REQUIREMENTS

To improve the GIGISim tool the analysis were carried to identify new facilities possible to implement in web-system and to meet users' specific requirements. We have already pointed out the necessity of proper nutritional diet assessment which requires calculations of total fat, proteins, carbohydrates and calories in patients' diet and the great majority of computer software dedicated for diabetes includes simple nutritional calculators. The role of the Glycemic Index on the daily glucose variation is difficult to identify without specially dedicated methods and only few systems available on the market, including GIGISim, actually include GI as a new factor, evaluating high-quality carbohydrates for diabetes diet.

The additional nutritional recommendations cited from the Canadian Diabetes Association (Guidelines for the Nutritional Management of Diabetes Mellitus in the New Millennium, 1999) which should be considered to provide a sufficient meal description, in the designed software:

- Eat at regular times
- Choose a variety of foods from all food groups
- Limit sugar and sweets
- Reduce the amount of fat you eat
- Include foods high in fibre
- Limit salt, alcohol and caffeine.
- Choose heart healthy fats such as canola and olive oil.

All those rules are easy to implement in the computer algorithms, and the only information required is the food type and the amount, which the prospective user may provide entering consumed products from the available database, including meal time dependencies.

Clinical survey was carried among diabetes patients in Krakow's Hospital and among members of the local Diabetes Association, to identify additional requirements and possible application of diabetes oriented software. Subjects were volunteers, type I and type II diabetes, all treated with insulin. Suggestions of patients are listed below and their implementation in GIGISim discussed in the following chapters. User recommendations:

- All individuals would like to receive nutritional counselling from registered dieticians as often as possible, preferably via Internet.
- Specific dietary recommendations and medications should be individualized to accommodate the person's preferences and lifestyle.
- Additional tools like diet diaries and statistical analysis of diet for longer time periods should be provided.

- User graphical interface should be facilitated to improve the process of data entering. Rarely patients are capable of weighing all consumed food products so estimations should be possible along with hints about possible amount consumed.

All those functionalities were analysed, and implemented in GIGISim Internet tool.

4 COMPUTER-AIDED DIABETES EDUCATION: A REVIEW

Although the impressive number of diabetes dedicated software is available in WWW, there are very few accessible solutions which would help consumers identify the effect of the novel, worldwide approved nutritional trend - the Glycemic Index. Although limited number of e-lerning diabetes tools complies with a full variety of requirements, discussed in previous sections, selected group of diabetes dedicated systems will be presented in this chapter, compared to GIGISim, to present the overview of interesting facilities and functionalities available.

Several investigators have pointed out the possibility of using the glucose and insulin plasma levels simulation models, to help diabetes interpret human carbohydrate metabolism (Lehmann E.D, 1997; Worthington DRL 1990) This approach to diabetes education was proved to be effective and numbers of mathematical models of the diabetes mellitus metabolism have been previously reported in literature.

The first presented in this section, well known AIDA software (Lehmann E.D, 1997) available since 1996, provides a simulation of glucose and insulin levels in the blood based on the glucose-insulin kinetics model. Authors have proved educational advantage of visualization methods like AIDA simulation over the traditional lectures in clinical research.

The DiasNet software (Plougmann S., 2001) have a clear clinical focus, however functional scope has been extended from being used by clinicians as advisory system to also being used by patients as an educational tool. Users can experiment with their insulin adjustment and meal sizes and analyse simulations based on human carbohydrate metabolism model.

Biermann and colleagues focused on the need for computer-aided learning tool for the education of patients and personal care of diabetes with insulin therapy. DIABLOG (Biermann E., 1990) is able to simulate glucose and insulin profiles of a 24 h period and display them graphically as curves. The subjects could vary the carbohydrate content of the meal, the injection time and dose of short-acting and intermediate acting insulin and observe simulation results calculated from mathematical model of glucose-insulin dynamics. This example is especially interesting insulin dose adjustment is considered the most difficult skill to develop for a new diabetes patient. However, opposite to the DiasNet solution this system doesn't support clinicians supervising so the results of the simulation must be carefully interpreted by potential users.

In addition to educative software described we should point out one which actually includes GI as a new factor, evaluating high-quality carbohydrates for diabetes diet. Home PC Editors' Choice (1995), NutriGenie, provides the GI ratings classifying commonly used food items into 3 categories: low, medium and high. NutriGenie Nutrient Analysis Tool controls saturated fat, cholesterol, sodium, proteins, fibre, vitamins and minerals of the patient's diet and is equipped with additional tools like DietTracker, Katogenic Meal Planner, Weight Tracker to control the blood glucose, blood pressure and serum triglycerides. Although the mentioned software is well featured we believe that a simple classification of GI doesn't provide a sufficient meal description. Graphic visualisation of blood glucose level changes for all possible GI values is the biggest GIGISim advantages over other software.

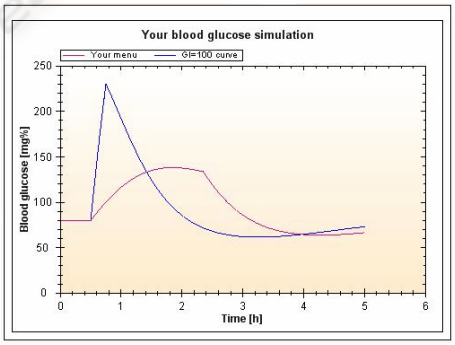

Figure 1: Example of the GIGISim meal simulation – plot compares blood glucose variation after consumption of 50g glucose and user defined meal.

5 GIGISIM – COMPLIANCE WITH NEW REQUIREMENTS

The main advantage of the GIGISim, emphasised in previous chapter is that the total effect of diet on blood glucose variations is presented on plots (Fig. 1). Graphical method illustrates metabolism reaction more clearly and intuitively then figures in GI tables

so patients treated with insulin analogues may adapt insulin type and doses to the pattern of blood glucose response, which is strongly correlated to GI. What is most important, the GIGISim will be clinician supervised system. All assessments will be presented to the user and also sent to the physician or dietician to approve new insulin treatment schema or introduce new eating habits, basing on the reports and nutrient analysis generated by the system.

Our system is an ASP.NET 2.0 web application and has been equipped with user friendly interface, providing help, tips and hints about food amount estimation, which was one of the most common user requirements. Next feature to implement would be a system of trackers and diaries

To control patient's progress in weight and blood glucose control. Also, the AI algorithms will be used to build intelligent Meal Planner and to individualize recommendations, to satisfy the person's taste preferences and lifestyle. To ensure comfort of usage the GIGISim may be easily migrated to the mobile devices like palmtops or mobile phones (Fig. 2).

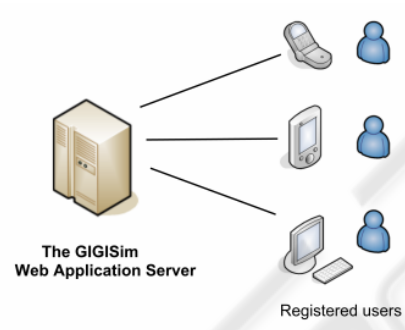

Figure 2: The ways of accessing the GIGISim on-line.

6 CONCLUSION

Nutrition management is a key component for the health and quality of life for people with diabetes but it is also probably one of the most complicated and complex long-term therapy. Many factors should be taken into account, like the individual's micro- and macronutrient, physical activity, lifestyle and medical needs. A meal and insulin dose planning requires experience from patients, their families and physicians. We believe the computer aided-diabetes therapy has a promising perspective if only the designed system will be able to assure and facilitate contact between the patient and his physician via web application, like GIGISim.

REFERENCES

CDA, 1999**.** *Guidelines for the Nutritional Management of Diabetes Mellitus in the New Millennium. A position statement by the Canadian diabetes association.* Canadian Journal of Diabetes Care, 23(3): 56–69.

Willett W, Manson J, Liu S, 2002. *Glycemic index, glycemic load, and risk of type 2 diabetes*. American Journal of Clinical Nutrition 76:274S-280S.v

Ludwig DS, 2002. *The glycemic index: physiological mechanisms relating to obesity, diabetes, and cardiovascular disease.* Journal of the American Medical Association 287: 2414-2423.

Jenkins, D.J., Kendall, C.W., Augustin, L.S., Franceschi, S., Hamidi, M., Marchie, A., Jenkins, A.L., & Axelsen, 2002. *Glycemic index: overview of implications in health and disease*. American Journal of Clinical Nutrition, 76 (suppl): 290S-298S.

T.M.S. Wolever, D.J.A. Jenkins, V. Vuksan, A.L. Jenkins, G.S. Wong, R.G. Josse, 1992. *Beneficial effect of low-glycemic index diet in overweight NIDDM subjects.* Diab. Care,15, 562–566.

Frost G,Wilding J, Beecham J., 1994. *Dietary advice based on the glycemic index improves dietary profile and metabolic control in type 2 diabetic patients*. Diabetic Med. 11:397–401.

A. Izworski, J. Koleszynska, R. Tadeusiewicz, J. Bulka, and I. Wochlik, 2005. *GIGISM (Glucose-Insulin and Glycemic Index Web Simulator) - The Online System Supporting Diabetes Therapy*. The IASTED International Conference on Telehealth Banff, Canada

A. Izworski, J. Koleszynska, R. Tadeusiewicz, J. Bulka, and I. Wochlik, 2006. *Internet Tools and Computer-Aided Diabetes Education: Introducing GIGISim Online*. Proceeding of Communications, Internet, and Information Technology, St. Thomas, USVI, USA

Lehmann E.D, 1997. *Interactive educational simulators in diabetes care*. Med. Inform. 22 (1997) 47–76.

Worthington DRL, 1990. *The use of models in the self-management of insulin-dependent diabetes mellitus.* Computer Methods & Programs in Biomedicine, vol.32, no.3-4, pp.233-9. Netherlands.

Lehmann E.D, 2001. *The freeware AIDA interactive educational diabetes simulator. A download survey for AIDA v4.0.* Med Sci Monit. May-Jun;7(3):504-15

Plougmann S, Hejlesen OK, Cavan DA., 2001. *DiasNet—a diabetes advisory system for communication and education via the internet.* Int J Med InformDec; 64(2-3): 319-30.

Biermann E., Mehnert H., 1990. *DIABLOG: a simulation program of insulin-glucose dynamics for education of diabetics.* Computer Methods and Programs in Biomedicine, Volume 32, Issues 3-4, July-August 1990, Pages 311-318.

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