Diabetes Assessment Scales, and the Impact of Health Education on Diabetic Patient Knowledge

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Received: April, 2018 Accepted: June, 2018

Abstract:

Objectives: To assess the diabetic patient condition using different diabetic scales and its relation to the blood glucose level and to assess the impact of health education message on their knowledge and to evaluate the possibility to create computational models for assessing diabetic patient condition automatically. **Method:** An interventional study was carried out on diabetic patients attending the diabetic clinic of Mansoura General Hospital, during the period of May to September 2015. **Results:** Random blood sugar showed significant positive correlation with Diabetes duration, BMI, depression and significant negative correlation with self-efficacy, empowerment, and social support, stage of change for diet and stage of change for exercise. However, diabetes activity showed significant positive correlation with different scales (Diabetes duration, BMI, social support, self-efficacy, empowerment, stage of change for diet and stage of change for exercise) except with random blood glucose and depression which showed significant negative correlation. Linear regression analysis showed that stage of change for exercise, social support, empowerment and BMI are common predictors for both random blood glucose and diabetes activity. Based on this study, two computational models could be concluded for predicting diabetes activity and random glucose level from different diabetes scales using artificial neural networks (ANNs). Improvement in the knowledge was observed after the health education setting as detected by the increase in the mean knowledge score. **Conclusion:** Computational models for diabetes condition assessment could be concluded where different variables under study were found related to the outcome of diabetes either management adherence or blood glucose level.

Key words: *Diabetes Scales; Diabetes Control; Health Education; Statistical Analysis; Artificial Neural Networks (ANNs).*

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Introduction

Diabetes is undergoing unprecedented growth globally. In low and middle-income countries, the prevalence of diabetes is likely to increase by over 60% from 2012 to 2030, compared to 20% in developed countries.[1] Diabetes has a great burden on health, it caused 1.5 million deaths in 2012.[2] In 2013 Egypt was ranked 8th highest country in the world in terms of diabetes rates. In 2015 the prevalence of type 2 diabetes (T2D) in Egypt was found to be around 15.6%

of all adults aged 20 to 79.[3]

The dramatic increase in the prevalence of diabetes is largely due to obesity and sedentary lifestyles. Depression appears to significantly increase the risk of developing Type 2 diabetes.[4] It also increases the risk for complications of diabetes such as persistent hyperglycemia, and overall reduced quality of life with respect to psychological, physical, and social functioning.[5]

Diabetes is largely a preventable disease. This is where diabetic health education and public awareness becomes critically important. The disease can be prevented with early institution of effective and consistent lifestyle modifications.[6] These life style modifications depend mainly on consuming healthy low calorie-diet and practicing physical exercises aiming to control hyperglycemia and to prevent diabetic complications.[7] In addition, there are other attempts to manage diabetes, including social support, self-efficacy, and empowerment.[8]

Social support and self-efficacy influence treatment adherence of patients with chronic illness including diabetes.[9] Social support is identified as a mechanism to successfully make and maintain changes.[10] Self-efficacy is defined as the confidence an individual has to make decisions and carry out self-management.[11] Increasing self-efficacy and social support for the patients with chronic illnesses including DM can influence treatment adherence and have a positive effect on health outcomes.[9]

Empowerment is defined as a “process by which individuals and groups gain power, access to resources and control over their own lives.[12] Empowerment is powerful in diabetic management; as patients are empowered when they have the knowledge, skills, attitudes, and self-awareness necessary to influence their own behavior and that of others to improve the quality of their lives.[13]

Since most of the diabetes assessment scales depend mainly on the patients’ responses, it can suffer from lack of accuracy because they are rather subjective and dependent on the patient understanding and knowledge making the assessment vary from patient to another. Additionally, carrying out the different diabetes scale questionnaires can be quite cumbersome and erroneous.[14] In order to avoid that, we enunciate the need for new ways to assess the influence of using the different diabetic scales on the assessment of blood glucose level and diabetes activity. Therefore, the current study was carried out to assess the diabetic patient condition using different diabetic scales and find its relation to the blood glucose level; and to assess the impact of health education message on their knowledge. Further, a new model is created to capture the influence of these scales on blood glucose level and diabetes activity using advanced computational techniques such as artificial neural networks (ANNs).

Method

This interventional study was carried out on diabetic patients of both genders attending the diabetic clinic of Mansoura General Hospital for 5 months period from May 1st, 2015 till September 30th, 2015 for obtaining their monthly drugs.

Sample size: the sample size was calculated online (dssresearch.com). A pilot study was done on 20 diabetic patients, from which the means of the scores of different questionnaires were obtained. The sample size was calculated according to these means and we took the largest sample size of 155 which was calculated according to the score of TDAQ. In that sample, the mean was 28.95 ± 5. By considering the worst acceptable mean as 27.95, the sample size was 155 with 95% confidence level and 80% study power. We increased the sample to 300. The patients were selected from the daily clinic list by a systematic sampling strategy, one in every 10 patients. The patients were given brief explanations of the objectives of the questionnaire. Patients were also assured of their anonymity and the confidentiality of their responses. The study was approved by the Mansoura faculty of medicine research committee.

Measures and data management: All diabetic patients of the study sample were subjected to a pre- coded interview questionnaire. The questionnaire was answered within 30 minutes and completed in the same visit. This questionnaire used to identify the following data: Socio-demographic characteristics include name, gender, age, residence, occupation, education, and family income. *Social Support:* Perceived social support related to diabetes from significant others, family, friends and health care professionals was measured by the Multidimensional Diabetes Questionnaire – Social Support subscale (MDQ-SS) [15]. The MDQ-SS consists of four items with four response options on a 1-4 rating scale. Total scores ranged from 4-16. *Depression:* Depression was measured by the Center for Epidemiologic Studies Depression Scale: (CES-D) [16]. The CES-D is a 20-item with questions pertaining to frequency of depressive symptoms experienced during the previous week [17]. Response options range from 0 (rarely) to 3 (most or all of the time), with the total score ranging from 0-60. *Self-Efficacy:* Self-efficacy for diabetes self-care was measured by the Multidimensional Diabetes Questionnaire - Self-Efficacy subscale (MDQ-SE) [15]. The MDQ-SE consists of 7 items with four response options ranging from “not at all confident” to “very confident.” producing a possible range of 7-28. *Empowerment: measured by Diabetes Empowerment Scale-Short Form (DES-SF).* The DES-SF is an 8-item Likert-type rating developed by researchers at the University of Michigan Diabetes Research Treatment Center (MDRTC), and have 5 Likert-type response choices: 1 = strongly disagree, to 5 = strongly agree. Scoring is performed by summing the total items completed and dividing by the number of items completed. *Diabetes Activity:* was measured by The Diabetes Activity Questionnaire (TDAQ) [18]. The TDAQ consists of 13 items measuring adherence to recommended diet, exercise, prescribed medication regimen, self-monitoring of blood glucose, management of abnormal glucose levels, and daily foot inspection. Response options ranged from “never” to “always. *Diet and Exercise Stage:* they were measured by the Stage of Diet Scale (SODS) and the Stage of Exercise Scale (SOES) [19], both consist of a five-point, ordered categorical scale and the responses ranged from 0-4. *Knowledge scale* [20]*:* 12 multiple choice questions common to type 1 and type 2 diabetes, e.g. normal blood glucose levels, complications, diet, exercise, self monitoring of blood glucose, annual check-ups, support services, and sick-days; two questions for people on oral medication/insulin only; and one question (sick-days) for people with type 1 diabetes only. *The intervention* was in the form of health education settings about diabetes related knowledge followed by reassessment by the same knowledge scale. *Investigation*: All the subjects are subjected to Random blood glucose, body weight, length and BMI**.**

Statistical techniques: The completed questionnaires were subjected to revision and the collected data were coded, processed and analyzed through SPSS (Statistical Package for Social Sciences)

(Standard version release 16.0). K-S was used to test the normality of different parameters. A descriptive analysis of the collected data was done in the form of frequencies and percentages. Determination of the internal consistency of different subscales was achieved by evaluating Cronbach alpha calculations. Correlation between different scales, blood glucose and BMI was examined by Spearman's correlation coefficient. The multiple linear regressions were used to assess predictors of random blood glucose and diabetes activity. $P \leq 0.05$ was chosen as the level of statistical significance.

Diabetes ComputationModels using Artificial Neural Networks

Based on the statistical analysis and using regression analysis, two prediction models were concluded for both diabetes activity and glucose level. Both models recognized the association between the different diabetes scales and both diabetes activity and glucose levels. As a further step, Artificial Neural Networks (ANNs) were used to predict this association more accurately. ANNs, in addition to correlating the independent variable to a number of dependent variables, further learn from the input-output data combinations. ANNs are adopted in this work because of their suitability for fitting input output functions that are nonlinear in nature. Artificial neural networks (ANNs) are inspired by the nervous system. They use a network of nodes, to arrive at outputs from inputs.[21] ANN does not require previous knowledge of the rules governing a system, making it more flexible to map between the input parameters and the output to get the best fit for a relationship model.[22] In this work, a two-layer feed forward network with what are known as sigmoid hidden neurons and linear output neurons were used to fit these multi-dimensional mapping problems (mapping from different diabetes scales to one outcome). The network was trained with Leven berg-Marquardt back propagation algorithm because of its suitability for this type of problems and because it out performs other training algorithms in datasets which are not very large [23]. The feed forward network is composed of an input layer and an output layer where each node’s influence on the nodes in the next layer is fed using a weight value. All these weights were accumulated according to the nodes states until reaching the output layer.[24]

Results

Three hundred diabetic patients with complete data were included in the study; their mean age was 48.9 ±10.7 years. Male and female patients accounted for 37.3% and 62.7%; respectively. About 50.7% of these patients were from rural areas versus 49.3% from urban areas. Nearly 37% were illiterate, 23.7% of our group had no enough income with 52.3% of them were not working. In our study, the different used scales showed good internal consistencies that were detected by reliability analysis (except the knowledge scale which showed a marginal consistency value) (MDQ-SS =0.879, CESD = 0.809, MDQ-SE = 0.925, DES-SF = 0.87 and TDAQ = 0.86) as shown in table (1).

Table 1: Reliability of different diabetes related scales

Diabetes related scales	Cronbach's Alpha	Cronbach's Alpha if item deleted	No of items
Multi dimension Diabetes Questionnaire – Social Support Subscale (MDQ-SS)	0.879	0.947	4
Center for Epidemiologic Studies Depression Scale (CESD)	0.809	0.843	20
Multi dimension Diabetes Questionnaire-Self-Efficacy Subscale (MDQ-SE)	0.925	0.931	7
Diabetes Empowerment Scale-Short Form (DES-SF)	0.87	0.892	8
Knowledge scale	0.50	0.624	15
The Diabetes Activity Questionnaire (TDAQ)	0.860	0.865	13

Random blood sugar showed significant positive correlation with diabetes duration, BMI, CESD and significant negative correlation with self-efficacy, empowerment, social support stage of change for diet and stage of change for exercise. However, diabetes activity showed significant positive correlation with different scales (Diabetes duration, BMI, social support, self-efficacy, empowerment, stage of change for diet and stage of change for exercise) except with random blood glucose and CESD which showed significant negative correlation (table 2).

Table 2: Correlation between random blood glucose and The Diabetes Activity with other diabetes related scales

Diabetes related scales	Random Blood Sugar	P value	Diabetes Activity	P value
Random Blood Sugar	1		-0.575**	<0.001
The Diabetes Activity	-0.575**	<0.001	1	
DM duration	.217**	<0.001	.161**	0.005
BMI	.202**	<0.001	.494**	<0.001
Social Support (MDQ-SS)	.468**	<0.001	.664**	<0.001
Depression (CESD)	.359**	<0.001	-.487**	<0.001
Self-Efficacy (MDQ-SE)	-.528**	<0.001	.891**	<0.001
Empowerment (DES-SF)	-.313**	<0.001	.650**	<0.001
Stage of Change for Diet (SODS)	-.503**	<0.001	.791**	<0.001
Stage of Change for Exercise (SOES)	-.596**	<0.001	.845**	<0.001

Using multiple regression analysis, it is evident that stage of change for exercise, social support, empowerment and BMI are common predictors for both random blood glucose and diabetes activity. Diabetes activity is a predictor for random blood sugar; however, self-efficacy and stage of change for diet are predictors for diabetes activity (table 3).

Table 3: Linear regression analysis of random bloom sugar and the Diabetes Activity.

Random Blood Sugar			The Diabetes Activity		
Predictors	**Unstandardized Coefficients B**	**P value**	**Predictors**	**Unstandardized Coefficients B**	**P value**
(Constant)	46.54	.306	(Constant)	11.914	<0.001
Stage of Change for Exercise (SOES)	-25.46	<0.001	Stage of Change for Exercise (SOES)	1.165	<0.001
Social Support (MDQ-SS)	5.538	.002	Social Support (MDQ-SS)	.232	<0.001
Empowerment	-2.121	.045	Empowerment	.095	.012
(DES-SF)			(DES-SF)		
BMI	2.570	.001	BMI	.064	.025
			Self-Efficacy (MDQ-SE)	.593	<0.001
			Stage of Change for Diet (SODS)	.886	<0.001
The Diabetes Activity	-3.521	.010			
Model prediction	41%			85%	
Model F	42.2			293.2	
Model p	<0.001			<0.001	

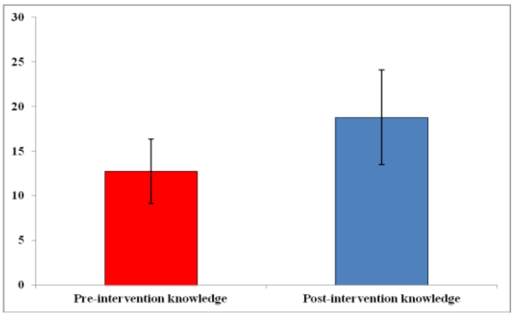

Figure (1): The mean and standard deviation of knowledge score before and after health education setting

Improvement in the knowledge was observed after the health education setting of the diabetic patients as detected by the increase of the mean score (pre-intervention score = 12.8 ±3.6 and post-intervention score=18.8 ± 5.3 (figure 1). Using artificial neural networks analysis, two prediction models were generated for both diabetes activity and random glucose level respectively. We could achieve high predictability for diabetes activity (R-Square = 0.95 – see figure 2a) while considerable predictability for Random glucose levels (R-Square = 0.75 – see figure 2b). Table 4 shows a comparison between linear regression and multilayer perception which is a sort of artificial neural networks. Results show that both models prediction error is very close.

Discussion

The growing incidence of diabetes accounts for more than 90% of all diabetes cases and the increased risk of premature illness and death and cardio vascular diseases with diabetes. In developing countries those most frequently affected are in the middle, productive years of their lives, aged between 35 and 64.[25] The increased number of diabetes is due to increasing population growth, ageing, urbanization and increasing prevalence of obesity and physical inactivity.[26]

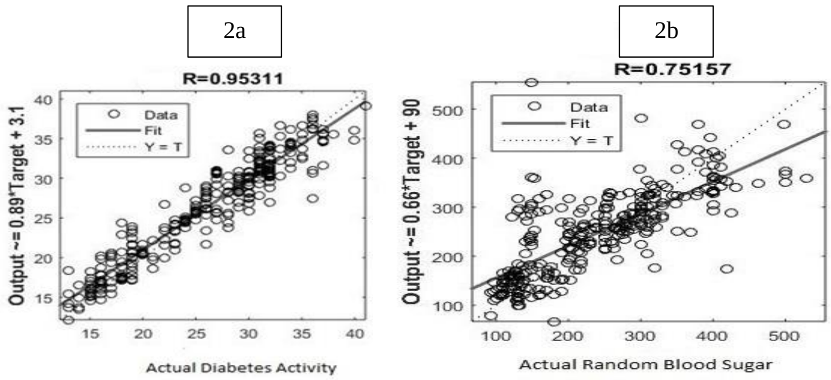

Figure (2a, b): Actual diabetes activity and random blood glucose versus predicted

Table 4: Comparison between Linear Regression and multilayer perceptron (ANN) models using mean absolute percentage error.

Model	Random Glucose Level	Disease Activity
Linear Regression	0.27	0.08
Mulitlayer Perceptron (ANN)	0.25	0.09

In this study, the different used scales showed good internal consistencies' that detected by reliability analysis regarding social support scale, depression scale, self-efficacy scale and diabetes empowerment. This is similar to, Scholz et al.[27] who reported high internal consistency concerning self-efficacy scale with samples from 25 nations ranged from 0.76 to 0.94. This is in agreement with Tabachnick and Fidell[28]; who also agreed that self-efficacy scale has high internal consistency. Consistently, more than 0.9 internal consistency of social support scale was reported by Tovar et al.[29] and Friedlander et al. 30. Empowerment scale also has high internal consistency reliability as mentioned by Tovar et al.[29] Good internal consistency concerning diabetic activity was reported by this study. In contrast, lower internal consistency was reported by Toobert et al.[31] (mean, 0.47). In this study, knowledge scale showed a marginal consistency value, however, Tovar et al.[29] declared that knowledge scale internal consistency was high. Knowledge scale assesses different aspects related to diabetes and in these multidimensional scales, high reliability may not be required as reported by Tovar et al.[29] who mentioned that high reliability may indicate redundancy of items.

Glycemic control is an important but complex aspect of diabetes management, with many factors necessary to maintain control.[32]

We declared that random blood sugar showed significant positive correlation with BMI and depression. In matching with us, Bakri[33] and Nisar[34] indicated that BMI is positively correlated with random blood glucose. Also, according to a recent study, 9% of patients with high random blood sugar were suffering from depressive disorders. At the same time, the association between depression and persistent hyperglycemia is reported by Petrak and Herpertz.[35]

In this study, random blood sugar showed a negative correlation with self-efficacy, empowerment, and social support. In agreement with us, Aalto et al.[36] and Trief et al.[10] reported that empowerment or self-efficacy and social support play a great role in the glycemic control and they should be researched together since such a strong correlation exists between them.

In this study, we reported that random blood sugar showed a negative correlation with stage of change for diet and stage of change for exercise. This is matched with Thomas et al.[37] who found that increased physical activity reduces the risk of overweight or obesity, therefore improves insulin sensitivity and control random blood glucose. Also, Tovar et al.[29] reported that low-calorie diets and physical activity are promoting weight loss and controlling blood sugar.

Significant positive correlation was detected in our study between diabetes activity, and different scales (Diabetes duration, BMI, social support, self-efficacy, empowerment, stage of change for diet and stage of change for exercise). Consistently, ADA **[38]** indicated that diabetes activities focused on low caloric diet and physical exercise are necessary for weight reduction. Also, Anderson et al.[7] reported that diabetic activities play a great role in weight management, as the reduction in excess body weight improves glycemic control and reducing random blood glucose.

In the current study, we found that diabetic activity showed a negative correlation with random blood glucose and CESD. Consistently, Daley et al.[8] found that having higher depression scores is associated with lower satisfaction with taking medication, lower satisfaction with testing blood glucose. However, higher satisfaction with taking medication and testing blood glucose were strongly associated with lower blood glucose level.

We could also show that computational models for the association between diabetes scales and both random glucose levels and diabetes activity can be concluded based on this study. We used artificial neural networks to create such models where both recorded high coefficient of determinants (R-square = 0.95 & 0.75) for diabetes activity and random glucose levels respectively compared to (R-square = 0.85& 0.42 - before using ANN). Using these models, we can further generate an autonomous tool that combines diabetes scales outputs and computes corresponding blood sugar level and diabetes activity. The use of artificial neural networks was found slightly better than linear regression for classifying random glucose but was found slightly worse for the classification of disease activity.

Life style intervention has shown effective significant changes over control in body weight and improving insulin sensitivity and that causes prevention of diabetes.[39] Health education for the diabetic patient involves individualized instruction, based on the assessment of patients' psychosocial factors and self-management skills and behaviors **[40]** and strategies to enhance and maintain the required level of physical activity and healthy diet.[34] The aim of diabetic education is to enable patients to acquire knowledge and skills to improve their diabetic state, identify barriers that hinder improvement, and attain problem-solving and coping skills to achieve effective self-care behavior.[41] Improvement in the knowledge was observed in our study after the health education setting of the diabetic patients. Similarly, Noris et al.[42] reported that diabetes health intervention has demonstrated improvements in diabetes knowledge. In a recent study examining the effects of six-month long lifestyle modification intervention, Kim et al.[43] found that the intervention, composed of a curriculum covering diet, exercise, and behavior modification techniques, led to significant improvements in diabetic knowledge and glycemic control.[29] Diabetes management requires knowledge and understanding of what to do and when and how to do it. As Bodenheimer et al.[44], declared; collaborative care and self-management education are important aspects to improve diabetic patients' knowledge. Also, knowing complications of diabetes is also helpful in reduction of morbidity and health cost.[45]

Conclusion and Recommendation

In this study, different variables such as psychosocial variables, empowerment, self-efficacy, and duration of diabetes were related to two outcomes of diabetes; management adherence and blood glucose level. Ongoing diabetes education and support are needed in health care systems. More interventions should be used with diabetic patients, resulting in increased support and knowledge; improvements in glycemic control and self-management behaviors. Further studies can be conducted to generate a generic tool that combines diabetes scales outputs and computes corresponding blood sugar level and diabetes activity using advanced computation techniques.

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