

Development of a Healthy Eating Index for patients with type 2 diabetes

Desenvolvimento de um Índice de Alimentação Saudável para pacientes com diabetes tipo 2

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ABSTRACT

Objective

This study sought to develop a dietary index for assessment of diet quality aiming for compliance with dietary recommendations for diabetes: The Diabetes Healthy Eating Index.

Methods

Cross-sectional study with 201 outpatients with type 2 diabetes (61.4±9.7 years of age; 72.1% were overweight; 12.1±7.7 years of diagnosis; 7.3±1.3% mean HbA1c). Clinical and laboratory evaluations were performed together with 3-day weight diet records. The dietary index developed included 10 components: "diet variety", "fresh fruits", "vegetables", "carbohydrates and fiber sources", "meats and eggs", "dairy products and saturated fatty acids", "oils and fats", "total lipids", "cholesterol", and "trans-unsaturated fatty acids". The performance of each component was evaluated using the Item Response Theory, and diet quality was scored from 0-100%.

Results

Overall, diet quality in this sample was 39.8±14.3% (95%CI=37.8-41.8%), and only 55 patients had a total diet quality score ≥50%. Good compliance was observed in only four index components: "total lipids", "variety", "fiber sources", and "dairy and saturated fatty acids". The components that differentiated patients with poor dietary quality from those with good dietary quality were "vegetables", "diet variety", "dairy and saturated fatty acids" and "total lipids". The greatest determinants of dietary quality were the components "diet variety", "vegetables", and "total lipids".

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Conclusion

This dietary index proposed assesses diet quality in compliance with the specific nutritional recommendations for diabetes. In clinical practice, this novel index may be a useful tool for the assessment and management of diet of patients with type 2 diabetes.

Keywords: Diabetes Mellitus Type 2. Diet. Food consumption.

RESUMO

Objetivo

Desenvolver índice dietético para avaliar a qualidade da dieta considerando a adesão às recomendações nutricionais específicas para diabetes: Índice de Alimentação Saudável para o Diabetes.

Métodos

Estudo transversal com 201 pacientes ambulatoriais com diabetes tipo 2 (idade=61,4±9,7 anos; 72,1% com excesso de peso; duração do diabetes=12,1±7,7 anos; HbA1c=7,3±1,3%) que realizaram 3 dias de registros com pesagem de alimentos, avaliação clínica e laboratorial. O índice foi elaborado com 10 componentes: "variedade da dieta", "frutas frescas", "vegetais", "carboidratos e fontes de fibra", "carnes e ovos", "laticínios e ácidos graxos saturados", "óleos e gorduras", "lipídeos totais", "colesterol" e "ácidos graxos trans-insaturados". O desempenho dos componentes foi avaliado pela análise de Teoria de Resposta ao Item e a qualidade da dieta foi convertida em escala de 0-100%.

Resultados

Nessa amostra, a qualidade da dieta foi de 39,8±14,3% (IC95%=37,8-41,8%) e somente 55 pacientes apresentaram pontuação total ≥50%. Boa adesão foi observada para apenas quatro componentes: "lipídeos totais", "variedade", "fontes de fibra" e "laticínios e ácidos graxos saturados". Os componentes que diferenciaram pacientes com baixa qualidade daqueles com boa qualidade foram "vegetais", "variedade", "laticínios e ácidos graxos saturados" e "lipídeos totais". Os maiores determinantes da qualidade da dieta foram os componentes "variedade", "vegetais" e "lipídeos totais".

Conclusão

O índice proposto avalia a qualidade da dieta de acordo com a adesão às recomendações nutricionais específicas do diabetes. Na prática clínica, esse novo instrumento pode ser uma ferramenta útil para a avaliação e manejo da dieta em pacientes com diabetes tipo 2.

Palavras-chave: Diabetes Mellitus Tipo 2. Dieta. Consumo de alimentos.

INTRODUCTION

Diabetes Mellitus is a major public health problem due to its high prevalence, morbidity, and mortality, as well as to the high costs involved in its management^{1,2}. Intensive control of hyperglycemia and hypertension, mainly using pharmacological therapy, has reduced the development of chronic micro- and, possibly, macrovascular complications of diabetes².

Lifestyle change have been recommended by the Brazilian Diabetes Society as an important intervention to improve diabetes management, and it includes weight loss, regular physical activity, healthy diet and behavior, and diabetes

self-management education³. The dietary recommendations from the Brazilian Diabetes Society includes monitoring the amount and type of carbohydrates ingested and reduction of total fat intake (saturated fatty acid intake, especially, should not exceed 7% of daily calories), cholesterol, and *trans*-unsaturated fatty acids. Furthermore, an increased intake of dietary fiber (14 g fiber/1000 kcal) and foods containing whole grains (one-half of all grain intake) is also recommended³.

In clinical practice, food intake is often assessed to support the production and implementation of nutritional recommendations to promote health, prevent illness, and improve nutritional status⁴. Therefore, dietary indexes have

been developed to evaluate the overall population diet quality of and can reveal the intake of various dietary components (food groups, nutrients, and diversity or variety) with one single variable⁵. The Healthy Eating Index is the most frequently used dietary index for the general population⁶. This index evaluates compliance with recommended food groups and specific nutrient intake according to dietary guidelines⁷, and it has been adapted to different populations and settings including Canada, Australia⁷, and Brazil⁸. Some authors⁹⁻¹¹ have evaluated the Healthy Eating Index in patients with diabetes. Only one transversal study⁹ evaluated the clinical characteristics that are related to diet quality in 151 Greek patients with type 2 diabetes. Cigarette smoking and alcohol consumption, female gender, presence of cardiovascular disease, peptic ulcer, obesity, and diabetic foot syndrome contributed to the adoption of a high quality diet (80% minimum score). Among the morbidities associated with diabetes, only diabetic nephropathy contributed to lower scores of diet quality⁹. Some other studies including a small size sample of Chinese people¹⁰ or Brazilian patients¹¹ found that a higher proportion of patients need diet quality improvements: 80.0 and 52.2%¹¹ of patients¹⁰, respectively. However, in those studies, the index was not adapted to include specific dietary recommendations for diabetes³. In fact, nutrition recommendations for people with diabetes are more demanding than those for the general population¹² regarding saturated fatty acids (7.0% as compared to 10.0% of total energy, respectively), cholesterol (200 mg/day as compared to 300 mg/day, respectively), and carbohydrates (monitoring the amounts and quality instead of reducing the consumption of the of foods high in sugar). Accordingly, it can be said that a dietary quality index specifically developed for these patients is necessary. Therefore, the present study sought to develop a dietary index for assessment of diet quality aiming for compliance with specific dietary recommendations for diabetes.

METHODS

This cross-sectional study was conducted in patients with type 2 diabetes, who were selected according to the World Health Organization criteria: age >30 years at onset of diabetes, no previous episodes of ketoacidosis or documented ketonuria, and initiation of insulin therapy (when present) at least 5 years after diagnosis¹³. The patients treated at the outpatient endocrinology clinic of the *Hospital de Clínicas de Porto Alegre*, State of *Rio Grande do Sul*, Brazil, who had not received any dietary counseling by a registered dietitian in the previous 12 months, were recruited (for information bias). Selection criteria were: age <80 years, Body Mass Index (BMI) <35 kg/m², serum creatinine <2.0 mg/dL (176 µmol/L), and normal liver and thyroid function tests.

A total of 317 eligible patients underwent clinical and laboratory evaluation. Hypertension was defined as blood pressure ≥140/90 mmHg on two separate occasions or use of antihypertensive drugs. Diabetic nephropathy was diagnosed on the basis of a random spot urine sample or 24 hours urinary albumin excretion. Micro- and macroalbuminuria were always confirmed when present¹⁴. A dilated fundus examination was performed and diabetic retinopathy was graded as present or absent. Economic status was evaluated by a questionnaire designed according to the Brazilian reality¹⁵. Current medications were determined based on a review of medical records of the patients' most recent visits preceding the dietary assessment. The patients were classified as current smokers, former smokers, or non-smokers and were self-identified as racially white or non-white. The frequency of physical exercise was graded according to their activities during a typical day¹⁶. Body weight and height were measured using an anthropometric scale and recorded to the nearest 100 g for weight and to the nearest 0.1 cm for height. BMI was then calculated as weight (kg)/height (m)². Waist circumference was measured once midway between the lowest rib margin and the iliac crest,

at the level of the umbilicus, and recorded to the nearest 1 cm. Measurements were made using flexible non-stretch fiberglass tape.

Blood samples were obtained after a 12 hours fast. Plasma glucose was determined using the glucose oxidase method, creatinine values using the Jaffe's reaction, glycated hemoglobin (HbA1c, reference range 4.7-6.0 %) using HPLC, total cholesterol and Triglycerides (TG) using enzymatic colorimetric methods, and High-Density Lipoprotein (HDL) cholesterol using the homogeneous direct method. Low-Density Lipoprotein (LDL) cholesterol was calculated using the Friedewald's equation ($LDL = \text{total cholesterol} - HDL - TG/5$). Urinary albumin excretion was measured using immunoturbidimetry, and urinary urea was measured using an enzymatic ultraviolet method. All tests were performed at the Clinical Pathology Laboratory of the *Hospital de Clínicas de Porto Alegre*.

The patients' regular diet was assessed using 3-day weighed dietary records (two non-consecutive weekdays and one weekend day), previously standardized and validated to our diabetic population^{17,18}. The patients were issued commercial scales and measuring cups. A detailed explanation was given, and the technique was demonstrated to each subject by a nutritionist. The within-person coefficient of variation used to estimate energy and macronutrient intake of the 3-day weighed dietary record was $<12\%$ ¹⁸.

The adequacy of the weight-records was assessed based on the protein intake *ratio* estimated by urinary nitrogen output, which ranged from 0.79 to 1.26¹⁸. Values outside this range were considered indicative of under- or overreporting¹⁸ thus 117 patients were excluded. The nutritional composition of dietary records was calculated using the NutriBase Clinical® Nutritional Manager software, United States Department of Agriculture Database for Standard Reference, version 20 (CyberSoft Inc., Phoenix, Arizona)¹⁹. Nutrient values of frequently consumed foods were complemented, when necessary, with data obtained from local manufacturers of specific industrialized foods.

Overall diet quality was assessed based on a combination of food groups and nutrients using the Diabetes Healthy Eating Index (DHEI). This index and the criteria for evaluation of diet variety were based on the original Healthy Eating Index²⁰. Food groups were described according to the recommendations from the Brazilian Dietary Guidelines¹², and the nutrient intake was described according to current Brazilian Diabetes Society recommendations³. The DHEI was based on 10 dietary components: 1) "Variety": number of food items reported in 3-day weighed dietary records; 2) "Fresh fruits": all fruits, raw, or cooked (servings *per* 1000 kcal/day); 3) "Vegetables": all vegetables, raw, and cooked (servings *per* 1000 kcal/day); 4) "Carbohydrates and fiber sources": component composed of the relationship between the consumption of whole grains and beans and the sum of total carbohydrate sources [refined and whole grains, sugar, and sweets (servings *per* 1000 kcal/day (fiber sources)); 5) "Meats and eggs": red and white meat, processed meats, and cooked eggs (servings *per* 1000 kcal/day); 6) "Dairy products and saturated fatty acids": component composed of milk, yogurt, and cheese (servings *per* 1000 kcal/day) and the proportion of energy intake from saturated fatty acids; 7) "Oils and fats": cooking oil, butter, margarine (servings *per* 1000 kcal/day); 8) Total lipids (% of total energy); 9) Cholesterol (mg/day), and 10) *Trans*-unsaturated fatty acids (% of total energy). A food item was considered for analysis when its reported intake had at least 50% of calories corresponding to 1 serving of its corresponding food group of the food group. Each item of the food preparations was considered for evaluation of diet variety²⁰, *i.e.*, a sandwich might contribute to both carbohydrates and meat groups.

The compliance of each individual component with the dietary recommendations was adjusted to daily energy intake reported by the patient and classified as "poor" (zero score), "fair" (score of 50%), or "good" (100% of score). The criteria applied and the servings considered for each food group are shown in Table 1. The

sum of scores of each individual component (maximum values=10) corresponded to the overall diet quality, scored on a scale of 0 to 100%.

The results were expressed as mean ± standard deviation, median (interquartile range), or number of patients (%), as appropriate. Values were considered statistically significant if *p* values were lower than 0.05 (two-tailed). Statistical analysis was performed using the PASW Statistics 18 for Windows software environment (IBM Corporation, 2010, New York, United States).

Assessment of each DHEI component was performed using a *a posteriori* analysis based on the Item Response Theory (IRT)²¹. Briefly, IRT is a set of mathematical models that represent the probability that an individual will give a certain response to an item as a function of the parameters of the item and the latent trait (here the dietary quality) of the respondent. The Graded Response Model, which is appropriate for

polytomous items, was used in this study²¹. The item response category characteristic curves describe the individual's probability to answer each category given his or her latent trait. Item information curves allow for the analysis of the extent to which a component of the instrument (the DHEI, in this case) contains the information needed to measure the parameter of interest (dietary quality). IRT was carried out using the *R* software (lrm package version 2.15.2, 2012, Vanderbilt University, Nashville Tennessee, United States)²².

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki, and all procedures involving patients were approved by the Hospital Research Ethics Committee of the *Hospital de Clínicas de Porto Alegre* under Protocol number nº 08-488, on November 7, 2008. Written Informed Consent was obtained from all patients.

Table 1. Diabetes Healthy Eating Index components: criteria used to evaluate compliance with the dietary recommendations in 2011 with type 2 diabetes patients from *Porto Alegre* (RS), Brazil, 2012.

	Components (daily intake)	Serving (kcal)	Compliance criteria*		
			Poor (0.0%)	Fair (50%)	Good (100%)
FIRST CLUSTER	1. Diet variety: number of items	-	<6.0	6.0-16.0	≥16.0
	2. Fresh fruits (servings per 1000 kcal)	70	<1.0	1.0-1.5	≥1.5
	3. Vegetables (servings per 1000 kcal)	15	<1.0	1.0-1.5	≥1.5
	4. Carbohydrates and fiber sources (servings per 1000 kcal)	150	<3.0 servings AND servings consisting predominantly of refined grains	<3.0 BUT at least 50.0% from fiber sources	≥3.0 AND at least 50.0% from fiber sources
SECOND CLUSTER	5. Meat and eggs (servings per 1000 kcal)	190	>1.0	0.5-1.0	≤0.5
	6. Dairy products AND saturated fatty acids (% of energy)	120	<0.75 servings/day of dairy OR saturated fatty acids intake >10.5% of energy	>0.5 serving of dairy AND saturated fatty acids <7.0% of energy OR >0.75 serving of dairy AND saturated fatty acids from 7.0 - 10.5% of energy	1.0-2.0 servings/day of dairy AND saturated fatty acids <7.0% of energy
	7. Oils and fats (servings per 1000 kcal)	73	>1.0	0.5-1.0	≤0.5
	8. Total lipids (% of energy)	-	≥45.0%	30.0%-45.0%	≤30.0%
	9. Cholesterol (mg/day)	-	≥300.0	200.0-300.0	≤200.0
	10. <i>Trans</i> -unsaturated fatty acids (% of energy)	-	≥1.5%	1.0-1.5%	≤1.0%

Note: *Criteria for compliance according to the Brazilian Diabetes Society dietary recommendations³, the Brazilian Dietary Guidelines¹² and the original Healthy Eating Index²⁰. The sum of scores of each individual component (maximum score=10) is the overall dietary quality, and it is scored on a scale from 0 to 100%.

RESULTS

The main clinical and laboratory characteristics of the sample are described in Table 2. Patients' mean age of was 61.4±9.7 years, 52.7% were female, 72.1% were overweight, 39.5% were categorized as lower middle class, mean years of diabetes diagnosis was 12.1±7.7 years, and mean HbA1c was 7.3±1.3%. The 3-day total daily energy intake was 1859±474 kcal, and the overall DHEI was 39.8±14.3% (95%CI=37.8-41.8%). Only 55 patients (27.4%) had a total DHEI score ≥50%.

The Diabetes Healthy Eating Index components were grouped into two clusters according to clinical criteria and to their effect on

the health of diabetic patients. The first cluster included components considered as sources of fiber ("fresh fruits", "vegetables", "carbohydrates and fiber sources") and the diet variety components. The second cluster included the components corresponding to food from animal sources and fats: "meats and eggs", "dairy and saturated fatty acids", "oils and fats", "total lipids", "cholesterol", and "trans-unsaturated fatty acids". Briefly, the components that differentiated the patients with low dietary quality from those with good dietary quality were "vegetables", "diet variety", "dairy and saturated fatty acids", and "total lipids". The greatest determinants of dietary quality were the components "diet variety", "vegetables", and "total lipids".

Table 2. Clinical and laboratory characteristics of 201 patients with type 2 diabetes from *Porto Alegre* (RS), Brazil, 2012.

Characteristics	Mean	SD	Median (interquartile range)	Patients (n)	%
Age (years)	61.4	± 9.7			
Female				106	52.7
White				176	87.6
Lower middle class				162	39.5
Duration of diabetes (years)	12.1	± 7.7			
Hypertension				127	64.8
Current smoking				24	11.9
Sedentary lifestyle				122	61.6
Micro- or macroalbuminuria				57	28.4
Diabetic retinopathy				177	36.3
BMI (kg/m ²)	28.5	± 4.4			
Overweight (BMI >25 kg/m ²)				145	72.1
<i>Waist circumference (cm)</i>					
Females	99.2	± 11.1			
Males	100.0	± 10.4			
<i>Diabetes treatment</i>					
Diet alone				11	5.5
Oral agents				124	61.7
Insulin or insulin plus oral agents				66	32.8
Hypolipidemic agents				36	18.0
Fasting plasma glucose (mmol/L)			7.9 (6.5-9.5)		
HbA1c (%)	7.3	± 1.3			
Total cholesterol (mmol/L)	5.2	± 1.1			
<i>High Density Lipoprotein-cholesterol (mmol/L)</i>					
Females	1.4	± 0.3			
Males	1.2	± 0.3			
LDL-c (mmol/L)*	3.1	± 0.9			
Triglycerides (mmol/L)			1.5 (1.1-2.1)		
Serum creatinine (µmol/L)			70.7 (61.9-88.4)		

Note: *Low Density Lipoprotein-cholesterol (LDL-c) was not calculated in two patients who had triglyceride values >4.48 mmol/L.

BMI: Body Mass Index; SD: Standard Deviation.

The levels of compliance (%) with the dietary recommendations are illustrated in Figure 1. Most patients had poor or fair compliance obtained for the components assessed by the DHEI. Good compliance was observed only for four components of DHEI: “total lipids” (64.3% of patients), “variety” (14.0% of patients), “fiber sources” (14.0% of patients), and “dairy and saturated fatty acids” (5.0% of patients).

DISCUSSION

The 10-component DHEI is the first tool developed for the assessment of dietary quality in patients with diabetes according to specific dietary recommendations for this population. It was found that outpatients with type 2 diabetes evaluated showed increased difficulty to comply with the dietary recommendations of some DHEI components, namely “carbohydrates and fiber sources”, “diet variety”, “dairy and saturated fatty acids”, and “oils and fats”. The greatest determinants of dietary quality were the components “vegetables” and “diet variety”, “dairy and saturated fatty acids”, and “total lipids”. Regarding overall dietary quality, most patients (73.6%) had a score of <50.0%, demonstrating need for improvement.

The first cluster comprised sources of fiber, components that have been associated with glycemic control²³, blood pressure²⁴, and metabolic syndrome prevalence²⁵ in patients with type 2 diabetes. Accordingly, the item “carbohydrates and fiber sources” was included considering the importance of the balance between refined-grain and whole-grain intake for metabolic control in diabetes³. Furthermore, the use of glycemic index and load may provide a modest additional benefit over that observed when total carbohydrate is considered alone³. However, the intake of fruit juices was not included in evaluation of the “fresh fruit” component because we believe that high glycemic index content should be considered. Nevertheless, in the present study, only 20% of patients reported intake of fruit juice (median intake, 87.5 [50-180] mL). Such low fruit juice intake hindered a more detailed evaluation of this factor.

The dietary components included in the second cluster have been associated with lipid profile^{3,26} and renal function^{27,28} in diabetes. The “dairy and saturated fatty acids” item is another component designed to determine the intake of low-fat or non-fat dairy products as recommended by the Dietary Approaches to Stop Hypertension (DASH) diet plan, which play a key role in reducing cardiovascular risk²⁹.

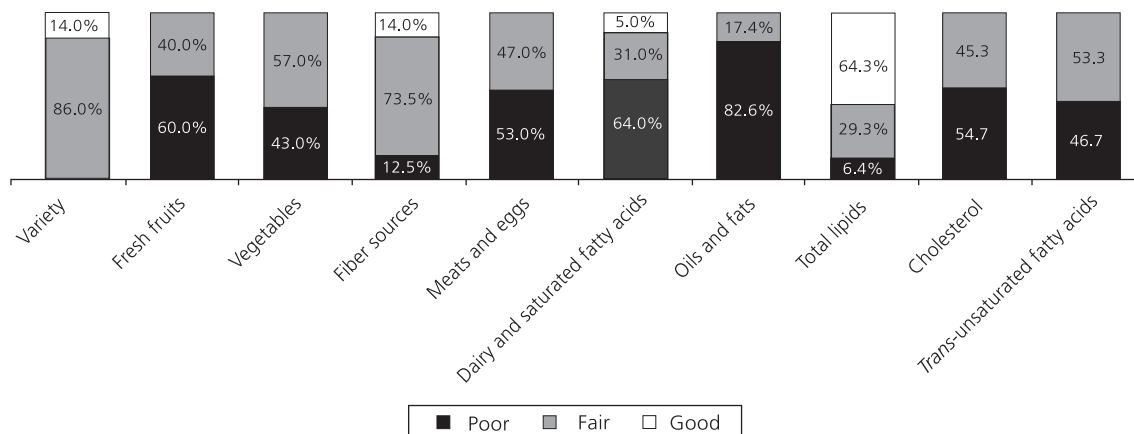


Figure 1. Levels of compliance with the nutritional recommendations obtained for the components assessed by the Diabetes Healthy Eating Index (DHEI) in 201 patients with type 2 diabetes.

Note: Black bar: poor compliance; Gray bar: fair compliance; White bar: good compliance.

Dietary indexes are useful tools in clinical practice because they enable the evaluation of overall diet quality using different dietary items⁵. However, to the best of our knowledge, there is no standard reference for evaluation of diet quality in patients with diabetes. A review of the literature did not reveal any validation studies on these indexes. Some authors evaluated the dietary quality of patients with diabetes using the Healthy Eating Index for the general American population^{9,30} or developed new scores according to their country guidelines^{31,32}. In the present study, the Healthy Eating Index was adapted to specific dietary recommendations for patients with diabetes³ and adjusted to Brazilian guidelines¹², yielding the DHEI. Due to the unique design of this novel study, it is difficult to compare it with previous studies. We believe that a dietary quality index developed specifically for patients with diabetes is necessary because dietary recommendations for these patients are more strict than those for the general population. In a pilot study of 40 patients with type 2 diabetes, dietary quality scores analyzed using the original Healthy Eating Index were higher than those calculated using the DHEI: $80.2 \pm 11.7\%$ versus $61.7 \pm 11.5\%$, respectively ($p < 0.001$, paired-samples *t* test, data unpublished); therefore, this observation needs to be confirmed by associations with socioeconomic characteristics and/or health outcomes in future studies with larger sample.

If the cutoff points for overall dietary quality proposed by the original HEI²⁰ had been used, the following values would have found: 38.3% of patients with poor dietary quality (diet quality score < 51), 61.7% of patients with regular dietary quality (score 51-80), and no patients with good dietary quality (score > 80). Even if the overall dietary quality cutoff proposed in a previous study on Greek patients with diabetes (score > 80)⁹ had been used, there would be no patients with a good-quality. It is known that a score of 50% does not characterize good dietary quality, but in the present study sample, only one patient obtained a score $> 75\%$. Therefore, cutoff points lower than

those previously used in other populations were established, which should be reviewed in a larger sample of patients with diabetes.

CONCLUSION

The Diabetes Healthy Eating Index evaluates overall diet quality in patients with diabetes aiming for compliance with specific dietary recommendations for patients with diabetes. In clinical practice, this novel index can be a useful tool for dietary assessment and management of diabetics. Furthermore, it can improve counseling on dietary habits by focusing on the dietary components that need improvement in the compliance with nutritional requirements. However, the DHEI cutoffs should be established and their validity tested in other samples of patients with diabetes taking into account possible associations with metabolic control parameters and even with "hard" outcomes, such as the chronic complications of diabetes.

CONTRIBUTORS

JP ANTONIO contributed to data collection and manuscript writing. SA CAMEY contributed to the statistical analysis, conception and revision of the manuscript. FM SILVA and MJ AZEVEDO contributed to the development of this index and critically reviewed the manuscript. JC ALMEIDA reviewed the manuscript, contributed to data interpretation and discussion of results. The final paper version was approved by all authors.

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