www.endocrinologia.org.mx

PERMANYER

Rev Mex Endocrinol Metab Nutr. 2021;8:57-64

ORIGINAL ARTICLE

REVISTA MEXICANA DE ENDOCRINOLOGÍA, METABOLISMO & NUTRICIÓN

Bioimpedance phase angle and body composition parameters associated with number of diabetes-related complications

Ángulo de fase por bioimpedancia y parámetros de composición corporal asociados con el número de complicaciones relacionadas a diabetes

Rubén Silva-Tinoco[1*], *Lilia Castillo-Martínez*[2], *Teresa Cuatecontzi-Xochitiotzi*[1], *Viridiana De la Torre-Saldaña*[1], *Daniela Rosales-Rosas*[1], *Arnulfo González-Cantú*[3,4], *María E. Romero-Ibarguengoitia*[3,4], *Enrique León-García*[5], *and Javier Serna-Alvarado*[5]

[1]Clinic Specialized in the Diabetes Management of the Mexico City Government, , Servicios de Salud Pública de la Ciudad de México, Mexico City; [2]Department of Clinical Nutrition, Instituto Nacional de Ciencias Médicas y Nutrición "Salvador Zubirán", Mexico City; [3]Research and Teaching Department, Hospital Clínica Nova, San Nicolás de los Garza, Monterrey, Nuevo Léon; [4]Medicine School, Universidad de Monterrey, San Pedro Garza García, Monterrey, Nuevo León; [5]Public Health Services of the Government of Mexico City, Mexico City. Mexico

ABSTRACT

In this cross-sectional descriptive study, body composition was evaluated by bioelectrical impedance in patients with type 2 diabetes (T2D) and contrasted with the differences in body composition parameters associated with the number of diabetes-related complications. In 648 patients with T2D and regular primary care in Mexico City, an initial and comprehensive evaluation with bioelectrical impedance monofrequency (50 Hz) analysis and an assesment of the presence of diabetes-related complications was obtained, including diabetic renal disease, diabetic retinopathy, peripheral diabetic neuropathy, history of macrovascular complications, and history of diabetic foot ulcer. Body composition parameters were different between patients with complications and patients with no complications, including extracellular water ($p < 0.024$), resistance ($p < 0.006$), reactance ($p < 0.001$), and phase angle (PA) ($p < 0.001$). In

RESUMEN

En este estudio descriptivo de corte transversal, la composición corporal fue evaluada por impedancia bioeléctrica en pacientes con diabetes tipo 2 y contrastada con las diferencias en los parámetros de composición corporal acorde al número de complicaciones relacionadas a diabetes. En 648 pacientes con diabetes tipo 2 y atención primaria regular en la Ciudad de México se realizó una evaluación inicial e integral incluyendo el análisis de composición corporal por impedancia bioeléctrica con monofrecuencia (50 Hz) y la evaluación de la presencia de complicaciones relacionadas a diabetes, que incluyeron: enfermedad renal diabética, retinopatía diabética, neuropatía diabética distal periférica, historia de complicaciones macrovasculares e historia de úlcera de pie diabético. Los parámetros de composición corporal fueron diferentes entre pacientes con complicaciones y pacientes sin complicaciones, incluyendo agua extracelular

Correspondence:
*Ruben Silva-Tinoco
E-mail: rosilva@sersalud.df.gob.mx

Date of reception: 19-04-2020
Date of acceptance: 15-05-2020
DOI: 10.24875/RME.20000026

Available online: 02-06-2021
Rev Mex Endocrinol Metab Nutr. 2021;8:57-64

subgroup analysis, according to the number of complications documented, higher extracellular water ($p < 0.001$), lower resistance ($p < 0.001$), lower reactance ($p < 0.001$), and lower PA ($p < 0.001$) were associated to a higher number of complications. PA, extracellular water, resistance, and reactance were different according to the diabetes-related complications profile implying a potential role for diagnosis and prognosis purposes.

Key words: Diabetes complications. Body composition. Phase angle. Impedance.

($p < 0.024$), resistencia ($p < 0.006$), reactancia ($p < 0.001$) y ángulo de fase ($p < 0.001$). En el análisis de subgrupos de acuerdo con el número de complicaciones documentadas, mayor agua extracelular ($p < 0.001$), menor resistencia ($p < 0.001$), menor reactancia ($p < 0.001$) y menor ángulo de fase ($p < 0.001$) se asociaron a un mayor número de complicaciones. El ángulo de fase, el agua extracelular, la resistencia y la reactancia fueron diferentes según el perfil de complicaciones relacionadas con la diabetes, lo que implica un potencial papel diagnóstico y pronóstico.

Palabras clave: Complicaciones de la diabetes. Composición corporal. Ángulo de fase. Impedancia.

INTRODUCTION

Type 2 diabetes (T2D) is characterized by insufficient insulin secretion, insulin resistance, altered fuel metabolism, and development of diabetes-specific complications in the eye, kidney, peripheral nerve, accelerated arterial disease in heart, brain, and lower extremities[1]. As a consequence of these complications, diabetes is the leading cause of new blindness in people of 20-74 years old, end-stage renal disease, and both neuropathy and non-traumatic lower extremity amputations[2]. Overall life expectancy in people with T2D is about 7-10 years shorter than people without diabetes[2].

Changes in body composition that accompanies the onset of diabetes and disease progression have an important impact on metabolism and insulin sensitivity[3]. Assessing the body's tissue composition might be an important part of the management of patients with T2D (people with diabetes [PwD]), given the role of fat and lean tissue in lipid and glucose metabolism[4]. Body composition assessment is suggested as part of comprehensive care in PwD. In clinical practice, body composition assessment is limited to anthropometric measurements as waist-hip ratio, body mass index (BMI) among others. It allows to identify patients with higher risk of weight associated comorbidities, to set goals in weight reduction, and to evaluate diabetes therapeutic interventions (pharmacological and non-pharmacological).

Bioelectrical impedance analysis (BIA) is a simple, non-invasive, easy to operate, and low cost for determining body composition[4]. The estimates of body composition by BIA (e.g., muscle mass or fat mass) may be biased by errors from underlying assumptions of body composition models[5]. Moreover, measurements determined directly by BIA have become promising alternatives in recent years[6,7]. Direct bioimpedance measurements comprise resistance (in ohms), reactance (in ohms), and the derived phase angle (PA) (in degrees). The PA is calculated as the arc tangent of the BIA vectors reactance and resistance, which describe the oppositions to an injected alternating electrical current of cell membranes, in the case of reactance, and body fluids, in the case of resistance[7]. The PA is an indicator of the amount of electrical charge that cell membranes can hold. Because the PA depends on total cell membrane mass, it could be a helpful index of cellular health and function. High PA suggests better cellular membrane integrity and a higher cell mass. PA has been identified as a valuable measurement for the diagnosis, monitoring, and prognosis of various disorders[8-10]. Dittmar reported that PA is a good indicator of catabolism and has an inverse correlation with T2D duration and glycemic control[11]. Moreover, the evidence about direct BIA parameters in ambulatory PwD and the utility to predict T2D complications is scant. Therefore, the aim of this study is to evaluate the performance of BIA to suspect the presence of diabetes-related complications and T2D severity according to the number complications in PwD in a primary care setting.

MATERIALS AND METHODS

Subjects

This study is a cross-sectional assessment of data collected from standard care of all consecutive PwD who participate in the DIABEMPIC program (Diabetes EMPowerment and Improvement of Care) from January 2017 to May 2019 at Clínica Especializada en el Manejo de la Diabetes en la Ciudad de México from the Mexico City government. DIABEMPIC program is a quality improvement of care initiative of the public primary healthcare system, designed to improve clinical outcomes in PwD through multicomponent interventions including interdisciplinary care and self-management education schemes[12,13]. The patients were referred from 36 primary outpatient centers located in urban areas of Mexico City and were beneficiaries of the INSABI (public health insurance, previously Seguro Popular). The study protocol was approved by the ethics and investigation in humans committee institutional review board (609-010-01-18). DIABEMPIC study was registered in ClinicalTrials.gov (Identifier: NCT04245267). The participation criteria were as follows: (a) T2D patients older than 18 years, (b) without any acute or chronic complication that required short-term hospital care, and (c) acceptance to participate after explaining the program. The data related to demographic characteristics, time since diagnosis, comorbidities, and physical medical examination were collected from medical records and confirmed during medical interviews.

Diabetes-related complications assessment

To determine the presence of diabetes-related complications, standardized criteria from international clinical practice guidelines[14] were implemented. For this study, five diabetes-related complications were considered: diabetic retinopathy, diabetic kidney disease, peripheral diabetic neuropathy, cardiovascular disease (ischemic heart disease, cerebral vascular disease, and/or peripheral arterial disease), and history of diabetic foot ulcer. Diabetic retinopathy assessment includes fundoscopy examination with mydriatic camera by an ophthalmologist. Diabetic kidney disease was defined by increased urine albumin/creatinine ratio (> 30 mg/g) in a random spot urine collection and/or decreased estimated glomerular filtration rate (< 60 ml/min/1.73 m^2 defined by Chronic Kidney Disease Epidemiology Collaboration equation). Abnormal sensitive and/or vibratory perception for distal diabetic neuropathy assessment through 1 g monofilament and 128 Hz tuning fork was evaluated[14,15]. Established cardiovascular complication presence was obtained from medical records and confirmed during medical interview and included the history and management of coronary artery disease symptoms and/or acute coronary syndromes, history and management of cerebral vascular disease and/or cerebral vascular event, and history and management of peripheral arterial insufficiency and/or peripheral arterial disease event. History of diabetic foot ulcer presence was asked during medical interview.

BIA

Whole-body bioelectrical impedance was measured using a tetrapolar and monofrequency equipment (Seca® 515/514, Hamburg, Germany). All measurements were performed in accordance with the reported technique[16]. Patients avoided alcohol intake 24 h before the measures. After 8 h of fasting and no vigorous physical activities, the patients removed all metallic objects that were in contact with the skin to avoid erroneous measurements. To obtain the impedance values, we used a frequency of 50 kHz. PA was obtained by a previous predictive formula[17].

Statistical analysis

We used mean and standard deviation to describe continues variables and absolute and relative frequency for categorical variables. The differences

Table 1. Clinical characteristics of the study population

Characteristics	n = 648
Female, %	67.7 (463)
Age, years	54.3 ± 11.4
Diabetes duration, years	11.5 ± 7.9
Hypertension, %	50.6 (346)
Obesity, %	44.6 (205)
Cardiovascular complications, %	3.1 (21)
Diabetic retinopathy, %	30.4 (208)
Diabetic renal disease, %	34.5 (236)
Diabetic foot ulcer history, %	2.9 (20)
Peripheral diabetic neuropathy, %	51 (349)
Weight, kg	72.4 ± 16.02
Body mass index, kg/m^2	29.8 ± 5.9
Glycated hemoglobin, %	9.69 ± 2.25

Data are presented as percentage (number) or mean ± standard deviation as indicated.

among the patients with no complication versus any complications were performed with Pearson's Chi-square test for categorical variables and unpaired Student's t-test for continuous variables. Furthermore, subgroups by number of complications (0-4) adjusted by age were assessed by an analysis of covariance (ANCOVA). $p < 0.05$ was considered statistically significant. Analyses were performed using SPSS version 21 (IBM, Armonk, NY, USA).

RESULTS

A total of 648 PwD were included in the study. Most patients were female (67.7%), 50.6% has hypertension and according to the BMI obesity criteria 44.6% had obesity. The patients had a mean age of 54.3 ± 11.4 and a mean disease duration of 11.5 ± 7.9 years. The most common diabetes-related complication was peripheral diabetic neuropathy (51%), followed by diabetic renal disease (34.5%), diabetic retinopathy (30.4%), cardiovascular complications (3.1%), and diabetic foot ulcer history (2.9%). These data are summarized in table 1.

As a result of the evaluation for the presence of diabetes-related complications, 212 patients (31%) were classified as absence of complications group and 472 patients (69%) in the presence of any complication group. Table 2 shows the comparison of BIA parameters between complications categories, divided by any complication and non-complication profile. Extracellular water, resistance, resistance/height, reactance, reactance/height, and PA were different among groups ($p < 0.05$).

Figure 1 shows means of extracellular water, resistance, reactance, and PA according to the number of diabetes-related complications. Higher extracellular water volume was observed across the incremental presence of complications ($p < 0.001$). Lower resistance, reactance, and PA were observed across the incremental presence of complications ($p < 0.001$).

DISCUSSION

This study showed how the presence of diabetes-related complications influence the body composition parameters obtained by BIA. We also report

Table 2. Bioelectrical body composition characteristics according to the presence or absence of diabetes-related complications

Variables	Total n = 648	No complication n = 212 (31%)	Any complication n = 472 (69%)	p
Weight, kg	72.45 ± 16.02	72.3 ± 15.1	72.5 ± 16.42	0.868
Glycated hemoglobin, %	9.69 ± 2.25	9.51 ± 2.22	9.77 ± 2.27	0.160
Total body water, l	32.6 ± 7.27	32.59 ± 6.72	32.66 ± 7.51	0.916
Extracellular water, l	15.07 ± 2.88	14.72 ± 2.56	15.23 ± 3.01	0.024
Hydration, %	85.06 ± 16.07	82.62 ± 13.35	86.16 ± 17.05	0.004
Resistance, ohms	591.02 ± 85.26	604.30 ± 78.67	585.07 ± 87.48	0.006
R/H, ohms/m	381.91 ± 64.75	389.34 ± 59.22	378.59 ± 66.86	0.045
Reactance,	50.35 ± 9.57	53.90 ± 7.92	48.77 ± 9.83	0.001
Xc/H, ohms/m	32.49 ± 6.52	34.66 ± 5.42	31.51 ± 6.74	<0.001
Phase angle, °	4.88 ± 0.69	5.1 ± 0.61	4.78 ± 0.70	<0.001
FFMI, kg/m^2	17.73 ± 2.71	17.73 ± 2.42	17.74 ± 2.83	0.960
Fat mass index, kg/m^2	12.3 ± 5.20	11.99 ± 4.23	12.45 ± 5.58	0.236
Fat mass, kg	28.80 ± 10.59	28.94 ± 10.04	28.73 ± 10.84	0.809
Fat mass, %	38.32 ± 10.55	38.52 ± 9.46	38.24 ± 11.02	0.733

R/H: Resistance/height; Xc/H: Reactance/height; FFMI: Fat-free mass index. Data are presented as mean ± standard deviation.

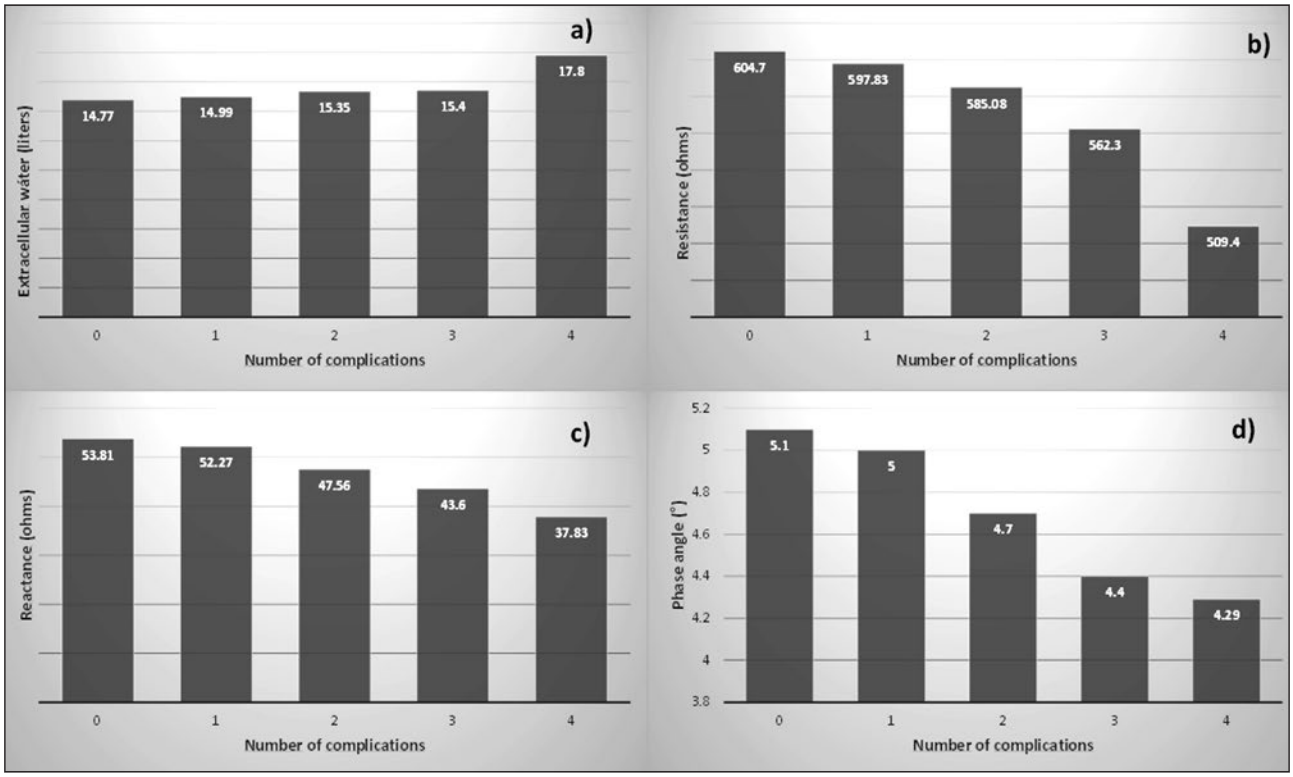

Figure 1. Bioelectrical impedance measures according to the number of diabetes-related complications in the study population (n = 648). Data are expressed as mean of **(A)** extracellular water; **(B)** resistance; **(C)** reactance; **(D)** phase angle. p < 0.001 age-adjusted differences were obtained in **(A, B, C,** and **D)** according to the number of complications by ANCOVA.

difference in BIA parameters (extracellular water, resistance, reactance, and PA) according to the number of diabetes-related complications, suggesting a diagnosis role of this parameters, but also a potential role as severity markers of the disease in PwD. To the best of our knowledge, this is the first study demonstrating progressive changes in body composition parameters according to the number of diabetes-related complications in ambulatory PwD.

In a preliminary report, we found a different PA among PwD with presence/absence of microvascular diabetes-related complications[18]. In this study, we found an inverse relation between the number of complications and PA, resistance, and reactance values. PA is calculated from the resistance and reactance values and it is associated with body cell mass. Reactance is related to the capacitance properties of the cell membrane and higher values indicate better health and cell membrane integrity, and resistance is the opposition offered by the body to the flow of an alternating electrical current, and it is inversely related to the water and electrolyte content of tissue[19]. Some patterns of body composition have been reported in PwD, among these are those characterized by loss of muscle mass (sarcopenia), by water retention, or by accumulation of adipose tissue[3]. These changes could explain the differences in body composition values found in this study and its association with the number of complications. Previously, in reports including patients not exclusively with diabetes have been informed about body composition phenotypes linked to worse prognosis[5]. For example, in patients with cardiovascular disease is well recognized that body composition subtypes characterized by low muscle mass are associated with higher mortality risk[20], the mechanism behind this association is not clear. Moreover, patients with chronic kidney disease are more likely to develop fluid retention and lean mass loss, both characteristics linked to worse prognosis[21,22].

On the other hand, PwD had a threefold higher risk of sarcopenia than subjects without diabetes explained by hyperglycemia, insulin resistance, increased inflammatory cytokines, and associated diabetes complications (peripheral neuropathy and reduction in motor neurons), and this is related with disability[23,24]. Insulin stimulates protein synthesis and defects in insulin signaling may lead to reduced muscle protein synthesis and increased protein degradation[25]. Protein degradation produces alteration in cell membrane integrity and shift of fluids from intracellular to extracellular space with a concomitant decrease in body cell mass, both lowering PA. Such disease-related alterations in fluid distribution are reflected in PA measures[26]. This study suggests the usefulness of BIA for identify low lean mass and fluid retention body phenotypes through extracellular water, resistance, reactance, and PA measurements, something that agrees with the presence of complications.

The number and severity of diabetes complications are independently associated with increased risk of mortality and hospitalization in primary care patients with diabetes[27]. In México, diabetes quality of care indicators such as mydriatic fundoscopy examination or diabetic kidney assessment are poorly executed[28]. According to our results, BIA could permit identify high-risk patients, and along with the vast related literature in other conditions, it could be suggested the incorporation of BIA to clinical decision-making process by health-care professionals in PwD. There were no differences in the BMI and weight of the patients in both groups (no complications vs. any complications) in this study, which suggest usefulness of BIA to identify populations that could have increased complications risk and worse prognosis, which are not identifiable by routine anthropometric evaluation. Changes in bioelectrical impedance parameters overtime that may occur as a result of therapeutic interventions (nutrition and exercise) to improve health should also be explored.

The present study had limitations such as it was performed in a single center; thus, a center-specific bias cannot be excluded, further validation in other populations is needed. Moreover, it is not only the presence of comorbidity but also its severity that influences alteration in bioelectrical impedance parameters and this was not evaluated, so we recommend analyzing severity of each complication and its association with BIA parameters in future studies. The prevalence of cardiovascular complications and history of diabetic foot ulcer were reported low in this study, it could be explained for the primary care setting the study was developed, and we suggest

to evaluate the usefulness of BIA in populations with higher prevalence of these complications. However, most patients with diabetes have regular care in primary care settings, and despite the low prevalence of these complications in this study, it was possible to obtain significative results, suggesting its usefulness at this setting.

CONCLUSIONS

PA, extracellular water, resistance, and reactance were different according to the diabetes-related complications profile implying a potential role for diagnosis and prognosis purposes.

ETHICAL DISCLOSURES

Approval was obtained by the Institutional Bioethics and Research Health Ministry Board (609-010-01-18).

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

FUNDING

No public or private funding was available for this research.

ETHICAL DISCLOSURES

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

REFERENCES

1. Melmed S, Koenig R, Rosen C, Auchus R, Goldfine A. Williams Textbook of Endocrinology E-book. Netherlands: Elsevier Health Sciences; 2019. p. 2239.
2. Harding JL, Pavkov ME, Magliano DJ, Shaw JE, Gregg EW. Global trends in diabetes complications: a review of current evidence. Diabetologia. 2019;62:3-16.
3. Guilherme A, Virbasius JV, Puri V, Czech MP. Adipocyte dysfunctions linking obesity to insulin resistance and Type 2 diabetes. Nat Rev Mol Cell Biol. 2008;9:367-77.
4. Duren DL, Sherwood RJ, Czerwinski SA, Lee M, Choh AC, Siervogel RM, et al. Body composition methods: comparisons and interpretation. J Diabetes Sci Technol. 2008;2:1139-46.
5. Barbosa-Silva MC, Barros AJ. Bioelectrical impedance analysis in clinical practice: a new perspective on its use beyond body composition equations. Curr Opin Clin Nutr Metab Care. 2005;8:311-7.
6. Colín-Ramírez E, Castillo-Martínez L, Orea-Tejeda A, Vázquez-Durán M, Rodríguez AE, Keirns-Davis C. Bioelectrical impedance phase angle as a prognostic marker in chronic heart failure. Nutrition. 2012;28:901-5.
7. Norman K, Stobäus N, Pirlich M, Bosy-Westphal A. Bioelectrical phase angle and impedance vector analysis-clinical relevance and applicability of impedance parameters. Clin Nutr. 2012;31:854-61.
8. Pineda-Juárez JA, Lozada-Mellado M, Ogata-Medel M, Hinojosa-Azaola A, Santillán-Díaz C, Llorente L, et al. Body composition evaluated by body mass index and bioelectrical impedance vector analysis in women with rheumatoid arthritis. Nutrition. 2018;53:49-53.
9. Beberashvili I, Azar A, Sinuani I, Shapiro G, Feldman L, Stav K, et al. Bioimpedance phase angle predicts muscle function, quality of life and clinical outcome in maintenance hemodialysis patients. Eur J Clin Nutr. 2014; 68:683-9.
10. do Amaral Paes TC, de Oliveira KC, de Carvalho Padilha P, Peres WA. Phase angle assessment in critically ill cancer patients: relationship with the nutritional status, prognostic factors and death. J Crit Care. 2018; 44:430-5.
11. Dittmar M, Reber H, Kahaly GJ. Bioimpedance phase angle indicates catabolism in Type 2 diabetes. Diabet Med. 2015;32:1177-85.
12. Silva-Tinoco R, Meza DG, Martinez DG, Orozco J, Romero-Ibarguengoitia ME, Torre-Saldañ DL, et al. Diabetes self-management education program effect on glycemic control and insulin dosing in poor diabetes literacy patients from urban areas in Mexico city-therapeutic education underuse and insulin overuse. Diabetes. 2018;67:648.
13. Delatorre-Saldaña VA, Silva-Tinoco R, Hernández J, Guzman EB, Castillo-Martínez L, Orea-Tejeda A, et al. Effect of an interdisciplinary care and diabetes self-management education program on weight among persons with social and clinical complex profile. Diabetes. 2019;68:655.
14. American Diabetes Association. 4. Comprehensive medical evaluation and assessment of comorbidities: standards of medical care in diabetes-2020. Diabetes Care. 2020;43:S37-47.
15. Meijer JW, Smit AJ, Sonderen EV, Groothoff JW, Eisma WH, Links TP. Symptom scoring systems to diagnose distal polyneuropathy in diabetes: the diabetic neuropathy symptom score. Diabet Med. 2002;19:962-5.
16. Lukaski HC, Johnson PE, Bolonchuk WW, Lykken GI. Assessment of fat-free mass using bioelectrical impedance measurements of the human body. Am J Clin Nutr. 1985;41:810-7.
17. Kyle UG, Genton L, Pichard C. Low phase angle determined by bioelectrical impedance analysis is associated with malnutrition and nutritional risk at hospital admission. Clin Nutr. 2013;32:294-9.
18. Silva-Tinoco R, Cuatecontzi-Xochitiotzi T, Castillo-Martínez L, León-García P, Cabrera-Gerardo D, Hernández J, et al. 677-P: bioimpedance phase angle in diabetes and change after an interdisciplinary care and diabetes self-management education program. Diabetes. 2019;68;677.

19. Barbosa-Silva MC, Barros AJ, Wang J, Heymsfield SB, Pierson RN. Bioelectrical impedance analysis: population reference values for phase angle by age and sex. Am J Clin Nutr. 2005;82:49-52.
20. Srikanthan P, Horwich TB, Tseng CH. Relation of muscle mass and fat mass to cardiovascular disease mortality. Am J Cardiol. 2016;117: 1355-60.
21. Hung SC, Kuo KL, Peng CH, Wu CH, Lien YC, Wang YC, et al. Volume overload correlates with cardiovascular risk factors in patients with chronic kidney disease. Kidney Int. 2014;85:703-9.
22. Lin TY, Peng CH, Hung SC, Tarng DC. Body composition is associated with clinical outcomes in patients with non-dialysis-dependent chronic kidney disease. Kidney Int. 2018;93:733-40.
23. Kim TN, Park MS, Yang SJ, Yoo HJ, Kang HJ, Song W, et al. Prevalence and determinant factors of sarcopenia in patients with Type 2 diabetes: the Korean sarcopenic obesity study (KSOS). Diabetes Care. 2010;33:1497-9.
24. Liccini AP, Malmstrom TK. Frailty and sarcopenia as predictors of adverse health outcomes in persons with diabetes mellitus. J Am Med Dir Assoc. 2016;17:846-51.
25. Sinclair AJ, Abdelhafiz AH, Rodríguez-Mañas L. Frailty and sarcopenia-newly emerging and high impact complications of diabetes. J Diabetes Complications. 2017;31:1465-73.
26. Lukaski HC, Kyle UG, Kondrup J. Assessment of adult malnutrition and prognosis with bioelectrical impedance analysis: phase angle and impedance ratio. Curr Opin Clin Nutr Met Care. 2017;20:330-9.
27. Young BA, Lin E, Von Korff M, Simon G, Ciechanowski P, Ludman EJ, et al. Diabetes complications severity index and risk of mortality, hospitalization, and healthcare utilization. Am J Manag Care. 2008;14:15-23.
28. Rojas-Martínez R, Basto-Abreu A, Aguilar-Salinas CA, Zárate-Rojas E, Villalpando S, Barrientos-Gutiérrez T. Prevalencia de diabetes por diagnóstico médico previo en México. Salud Pública Méx. 2018;60:224.