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Effect of a Nutritional-Educational Intervention with a Mexicanized Mediterranean Diet (DMM) on the Anthropometry and Biochemistry of Overweight and Obese Adults in Mexico

Efecto de una intervención nutricia-educativa con dieta mediterránea mexicanizada (DMM) en la antropometría y bioquímica de adultos con sobrepeso y obesidad en México

Cintia Carolina Amaral Montesino
University of Monterrey, Mexico (Cintia.amaral@udem.edu)(https://orcid.org/0000-0002-8119-6046)
Claudia Cecilia Radilla Vásquez
Universidad Autónoma Metropolitana, Mexico (cradilla@xoe.uam.mx) (https://orcid.org/0000-0001-9161-1904)Ana
Ana Esther Rodríguez Estrada
University of Monterrey, Mexico (ana.estrada@udem.edu) (https://orcid.org/0000-0002-0301-9394)
Andrea Abrego Sanchez
University of Monterrey, Mexico (andrea.abrego@udem.edu) (https://orcid.org/0000-0003-0846-0194)
Monica Alejandra Díaz Granados
University of Monterrey, Mexico (monica.diaz@udem.edu) (https://orcid.org/0000-0003-1769-7716)
Ricardo González Ponce
University of Monterrey, Mexico (ricardo.gonzálezp@udem.edu) (https://orcid.org/0000-0003-4307-9129)
Augusto Salinas Flores
University of Monterrey, Mexico (augusto.salina@udem.edu) (https://orcid.org/0000-0001-7513-6285)
Olga Carolina Rojas García
University of Monterrey, Mexico (carol@hotmail.com) (https://orcid.org/0000-0001-77177072)

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ABSTRACT

Mexico has high rates of obesity and overweight, associated with chronic non-communicable diseases. The Mediterranean diet (MD) has been shown to be useful in combating cardiovascular diseases, obesity, diabetes and metabolic syndrome; it is adaptable to Mexico since it can use local foods with a nutritional density similar to those of the Mediterranean. The objective of the study was to evaluate the effect of a nutritional-educational intervention with the Mexicanized Mediterranean Diet (MMD) through anthropometry, glucose, lipids, insulin and interleukin 6 in overweight or obese adults in Mexico. A longitudinal, prospective 6-week study. The MMD intervention group involved 16 subjects and the control group with a regular diet involved 13. All received nutritional education. Anthropometric measurements and blood tests were taken. In the group treated with DMM, weight and BMI decreased in 75% of participants, 62.50% reduced body fat percentage, 37.50% visceral fat, waist-to-height (W/H) ratio in 32%, waist-to-hip (W/H) ratio and waist circumference in 25%. Glycemia decreased in 12.5%, insulin and HOMA decreased in 62.5%, glycated hemoglobin in 43.5%, triacylglycerols, cholesterol and LDL in 68.75%, VLDL in 62.5%, atherogenic index in 75%, IL-6 in 100%, HDL increased in 50%. Adherence to DMM improved with education. The Mixed Effects Model Analysis Test and the Fisher LSD Test were used to perform multiple comparisons between groups after finding a significant difference. The intervention with MMD had an effect on the reduction of weight and anthropometric-biochemical parameters in the population, reaffirming the effects of MMD evidenced in the scientific literature.

Palabras clave:
Dieta mediterránea mexicanizada, sobrepeso, obesidad

RESUMEN

México presenta elevadas tasas de obesidad y sobrepeso, asociadas con enfermedades crónicas no transmisibles. La dieta mediterránea (DM) ha demostrado ser útil para combatir enfermedades cardiovasculares, obesidad, diabetes y síndrome metabólico; es adaptable a México ya que puede emplear alimentos locales con densidad nutricional similar a los mediterráneos. El objetivo del estudio fue evaluar el efecto de una intervención nutricia-educativa con Dieta Mediterránea Mexicanizada (DMM) a través de la antropometría, glucosa, lípidos, insulina e interleucina 6 en adultos con sobrepeso u obesidad de México. Estudio longitudinal, prospectivo de 6 semanas. El Grupo intervenido con DMM involucró a 16 sujetos y el grupo control con dieta habitual a 13. Todos recibieron educación nutricional. Se tomaron medidas antropométricas y exámenes de sangre. En el grupo intervenido con DMM, el peso y el IMC disminuyeron en 75% de los participantes, el 62.50 % redujo porcentaje de grasa corporal, el 37.50 % de grasa visceral, el índice cintura-talla (C/T) en el 32%, el índice-cintura/cadera (C/C) y la circunferencia de cintura en el 25 %. La glucemia disminuyó en el 12.5 %, insulina y HOMA disminuyeron en el 62.5 %, la Hemoglobina glucosilada en el 43.5%, los triacilgliceroles, colesterol y LDL en el 68.75%, VLDL en el 62.5 %, el índice aterogénico en el 75%, IL-6 en el 100 %, la HDL se incrementó en el 50%. La adherencia a la DMM mejoró con la educación. Se utilizó la Prueba de Análisis de modelos de efectos mixtos y la Prueba de Fisher LSD para realizar comparaciones múltiples entre grupos con diferencia significativa. La intervención con DMM tuvo efecto en la reducción del peso y de los parámetros antropométricos-bioquímicos en la población reafirmando los efectos de la DM evidenciados en la literatura científica.

Introduction

The worldwide prevalence of obesity has tripled in the last 40 years (1). Mexico has the highest rates of obesity and overweight in the world (2). In Mexico, 33% of school-age children, 35% of adolescents and more than 75% of adults experience obesity or overweight (3)(4), which are associated with the development of chronic noncommunicable diseases. The positive imbalance in energy consumption is the main cause. There is a higher energy intake and a decrease in energy expenditure, leading to fat accumulation. Diet determines body weight gain and at the same time is a tool in the prevention, management and treatment of these disorders (1). Health and nutrition surveys conducted in Mexico have shown that the food quality of the Mexican population is not adequate and that a large part of the population does not comply with the dietary recommendations. There is an excessive consumption of added sugars and saturated fats, low intake of fruits, vegetables, legumes or seafood and nuts (4). Throughout history, diet has played a crucial role in sustaining human life. It encompasses the consumption of common foods and specific groups of people and is closely related to cultural practices, lifestyle and food availability (5). Each type of diet has different nutritional profiles, emphasizing specific groups, macronutrients and bioactive components that can exert various effects on aging processes and disease risk. Understanding the influence of various types of diet and related diseases can serve as a basis for personalized dietary recommendations and lifestyle interventions aimed at promoting healthy aging and mitigating age-associated morbidities (5). Sustainable healthy diets promote a higher intake of plant-based foods and a lower intake of animal-based foods, and the Mediterranean diet (MD) is an excellent example (6). Recent studies show that a sustainable healthy diet based on the Mediterranean diet is associated with lower weight, body mass index (BMI), waist circumference, waist-to-hip ratio, trunk fat, total fat and lean mass (7) (8). Its richness consists of the nutritional contribution of the foods that constitute its base, the mono and polyunsaturated fatty acids, vitamins A, C and E, antioxidants and lycopenes that it contains. It is rich in vegetables, legumes and fruits, whole grains, olive oil, seeds and nuts, fish, low-fat dairy products and wine, accompanied by a low intake of red meat and sodium. Fresh vegetables are consumed in lightly cooked salads dressed with olive oil. The Mexicanized Mediterranean diet (DMM) arises as an adaptation of the DM to Mexico, which has points of contact with the milpa diet, as well as with the traditional Mediterranean diet. It promotes the consumption of very common and representative foods of Mexico such as corn, avocado, cocoa, legumes, almonds, chia, nopales, chayote, chard, watercress, zucchini, cilantro, jicama, peanuts, pepitas, pistachios, guava, tuna, zapote, corn, amaranth, oats, yucca, sweet potato, potato, rice and lentils, among others (9). It is a healthy eating pattern that combines products from the traditional Mediterranean diet with Mexican foods with similar nutritional properties. Evidence points to its richness in fiber, antioxidants, polyphenols such as resveratrol, beta-glucans and fructooligosaccharides (10).

The use of avocados stands out, as Mexico is the world's leading producer of avocados. They are rich in vitamins, minerals, fiber and phytochemicals. Avocado consumption has been associated with reduced risk of metabolic syndrome, cardiovascular disease, and overweight or obesity due to increased satiety and decreased appetite (11). It also provides a high percentage of fatty acids, approximately 15% of its weight, predominantly monounsaturated fatty acids such as oleic acid. It is proposed that the high concentrations of these monounsaturated fatty acids in avocados can improve the lipid profile, as well as reduce body weight in people with obesity (11) (12). Betasitosterol, one of its bioactive components, regulates cholesterol levels and reduces the risk of atheroma plaque formation. They are rich in fiber, including soluble hemicelluloses and pectins, which are metabolized by intestinal microorganisms to produce short-chain fatty acids (12) (13). Furlan et al stated in their study that participants who consumed for 6 days a hyperlipidemic diet where butter was replaced by avocado oil improved the postprandial profile of insulin, glycemia, total cholesterol, low-density lipoproteins, triglycerides and inflammatory parameters, such as C-reactive protein and interleukin-6. In addition, they proposed that avocado pulp oil from Mexican variants has been shown to exhibit marked anti-inflammatory activity by inhibiting the Cox 1 and Cox 2 cyclooxygenase enzymes in a similar manner to ibuprofen (14). Ford et al. proposed that adding avocado to salsa improves the absorption of vitamin A, as well as lycopene and beta-carotene, while adding it to salad increases the absorption of alpha-carotene, beta-carotene and lutein. It helps to absorb beta-carotene from tomato sauce, carrots and improves the conversion of beta-carotene to vitamin A, as well as lutein and zeaxanthin which accumulate in the macula of the retina and correlate with lutein concentrations in the brain (12).

Cocoa is another outstanding component; it is a 100% Mexican food with a marked therapeutic aspect. Regular consumption of cocoa powder and/or dark chocolate has been associated with decreased anthropometric parameters in overweight and obese individuals such as body weight, body mass index and waist circumference (15). Natural cocoa has a regulating effect on glucose and insulin levels (9) (15). Due to the high level of polyphenols and derived products, it is a natural source of antioxidants in Latin American diets and contains the highest concentration of flavonoids. The advantages of its consumption include glycemic control, cardioprotective, anticarcinogenic, anti-inflammatory and antioxidant properties (15). Scientific evidence suggests that it reduces glucose levels and the risk of diabetes, increases nitric oxide, which regulates blood pressure and reduces hypertension. The presence of phenolic phytochemicals and flavonoids in cocoa beans provide protection at the cellular level against oxidative stress and free radical damage. It boosts mood and cognitive performance and delays aging (15). Chia seeds are a functional food that is present in this type of diet.It presents a high content of polyunsaturated fatty acids, mainly α-linolenic acid, which represents approximately 60% of all its fatty acids. They are considered the richest vegetable source of omega-3 fatty acids with anti-inflammatory, brain-enhancing, psychological and cholesterol-lowering properties (16)(17). Its ratio of omega-6 and omega-3 acids is correct. It is a vegetable protein source, being protein between 18 and 24% of its mass (16) (17). Research shows that chia seeds have a great nutritional profile and tremendous health-enhancing characteristics. It is reported to improve blood lipid levels, reduce blood pressure, blood glucose and also strengthens the immune system and has antimicrobial action. They have the ability to suppress the most common current chronic diseases and several types of cancer (17).

Nopal cactus is a cactus of Mexican origin, it is known for its high concentration of polyphenols that exhibit antioxidant and anti-inflammatory properties. It is considered a functional and prebiotic food; it is rich in soluble and insoluble fiber. It is used as an anti-ulcerogenic antiulcerogenic, antioxidant, antidiarrheal, anti-inflammatory, hypoglycemic, neuroprotective and antihypercholesterolemic. Its composition is very rich in ascorbic acid, vitamin E, carotenes, dietary fiber, amino acids and antioxidant compounds. It is widely used in traditional Mexican medicine (11). The consumption of nopal cactus lowers blood levels of glucose, total cholesterol, c-HDL and triglycerides in patients with obesity (18). The soluble fiber it contains is related to a decrease in glucose, cholesterol and triglyceride levels and an increase in c-HDL. This cactus has gallic acid in its flowers, which exhibits high antioxidant activity, which collaborates in the reduction of DNA damage and elimination of radicals (18)

Nutritional education interventions have proven to be useful strategies to modify behaviors and habits in populations of any age. They are the complement for planning actions to prevent and control diseases related to overweight and obesity. Their characteristics, methods and forms of teaching must be tailored to the population group for which they have been designed, being similar in different geographical locations. The task is not simple; among the challenges to be overcome is to contribute to reducing health and food security problems in the populations, as well as to promote long-term behavioral change related to food. The objective of this study was to determine the effect of a nutritional-educational intervention combined with the Mexicanized Mediterranean Diet (MDM) on anthropometry and biochemistry in overweight and obese adults from northern Mexico. This study is one of the first to evaluate the effects of the Mexicanized Mediterranean Diet (MDD) on anthropometric and biochemical variables in overweight or obese adults in Mexico.

Method

The study consisted of a longitudinal and prospective nutritional-educational intervention with a 6-week follow-up. It was approved by the Ethics Committee of the Universidad Internacional Iberoamericana (UNINI) with registration CR-155 and complied with the guidelines of the Declaration of Helsinki. A total of 29 subjects participated and 2 groups were randomly formed. All of them signed the informed consent form. Group 1 intervened with DMM involved 16 subjects and Group 2 control with Habitual Diet 13 subjects. Inclusion criteria included being between 18 and 78 years of age, and having a body mass index (BMI) of overweight or obesity, having signed the informed consent form, having an approving attitude towards changing eating habits, willingness to adhere to the proposed dietary plan and attending the educational sessions. Both groups received the same nutritional education. Anthropometric measurements and blood determinations were performed at baseline and after 5 weeks of the intervention.

Collection of personal data:

An instrument was designed to carry out anamnesis and evaluate nutritional status, medical history, food allergies or intolerances, medication, and the use of mineral and vitamin supplements. The instrument was self-administered and included a food consumption frequency questionnaire, as well as the 24H reminder a nutrition knowledge assessment questionnaire and a questionnaire of adherence to the Mexicanized Mediterranean diet (DMM).

Anthropometry:

The Tanita Fitscan BC-533 body analyzer scale was used to determine current weight, fat percentage and visceral fat percentage. The Seca 213 stadiometer was used to determine height, using the validated technique for measuring height. Weight and height measurements were required to determine the Body Mass Index (BMI) which was analyzed by age and sex. A Body Flex Sana Flex anthropometric tape was used to determine wrist circumference, waist circumference and hip circumference in order to calculate the waist-to-hip ratio (WHR) and waist-to-height ratio (WHR).

Blood samples:

Determinations of 9 metabolites were made: glucose, insulin, glycosylated hemoglobin, LDL, HDL, VLDL, triacylglycerides, total cholesterol, Interleukin 6 in two measurements. The samples were processed at the Clinical Analysis Laboratory of the University of Monterrey, Nuevo Leon, Mexico.

Educational-nutritional intervention:

The educational intervention consisted of 2 face-to-face individual counseling sessions and 3 group counseling sessions. Individual counseling included explanation of the DMM meal plan and food combining, review of laboratory tests, as well as personal nutritional and anthropometric assessment. They were informed of the need to moderate the consumption of salt, simple sugars and saturated fats and were invited to make changes in their eating habits, with emphasis on reducing the consumption of ultra-processed foods and increasing the consumption of fiber and foods with high nutritional density.

Design and establishment of the Food Plan:

DMM's dietary plan included carbohydrates, lipids and proteins in adequate amounts to meet the requirements of the correct diet according to NOM-043 (4). It was designed according to the Mexican System of Equivalents (SMAE) on an individualized basis. In group 1 the proposed diet was hypocaloric, with a deficit of 500 kcal from the Total Energy Expenditure (TEE). Basal energy expenditure (BEE) was calculated according to the Harris Benedict equation for women and men. Calories were distributed 55 % carbohydrates, 20 % proteins and 25 % lipids (5). The fat used was olive oil for cold preparations and avocado oil for cooking. Regular consumption of vegetables (2 servings per day free quantity), fruits (3 servings/day), legumes (3 times/week), fish (3 times/week), red meats and sausages were reduced to occasional consumption (1 time/week). Four meal times were maintained to control insulin levels, with overnight fasting without consuming food from 10 to 12h. Components of the pre-Hispanic Mexican diet such as corn, beans, nopal, chia, avocado and cacao were included.

Statistical analysis:

Prism Graph Pad software version 9.5.1 of the year 2023 was used. The Shapiro-Wilk test was used to contrast the fit or not to the normal distribution. The variables analyzed showed a normal distribution. The level of statistical significance considered was $p=0.05$ and $p<0.05$. The mixed-effects model analysis test and the Fisher LSD were used to perform multiple comparisons between groups after finding the existence of significant difference.

Results

In group 1 consuming the DMM meal plan 75 % of the members decreased their weight and BMI after the intervention, 62.5 % reduced body fat percentage, 37.5 % visceral fat, waist/height ratio by 32 %, waist/hip ratio and waist circumference by 25 % as shown in Table 1.

Table 1. Percentage of participants with variations in anthropometric parameters after the intervention in group 1 and 2

Parameters	**Group 1 DMM Intervention**	**Group 2 Habitual Diet Control**
Weight	75%	46.15 %
BMI	75%	46.15 %
Waist circumference	25 %	46.15%
Waist-to-size ratio	32%	53.84%
Waist/hip ratio	25%	53.84 %
Percentage of fat	62.50 %	61.3 %
Visceral fat	37.50 %	23.07 %

Figure 1 shows the results of the Fisher LSD test for anthropometry, denoting the existence of statistically significant difference in 5 parameters which are: Weight, BMI, waist/height ratio, waist/hip ratio, waist circumference analyzed in the DMM Intervention group at measurement 1 (pre-intervention) and measurement 2 (post-intervention). This statistically significant difference indicates that the values are substantially different according to statistical tests, which means that the numbers are reliably different and that there was a noticeable change. Table 2 shows the p-values for all the parameters analyzed, demonstrating the existence of values of $p=0.05$ or $p<0.05$ for the aforementioned parameters in group 1, however, in group 2 no significant difference was found when comparing the parameters.

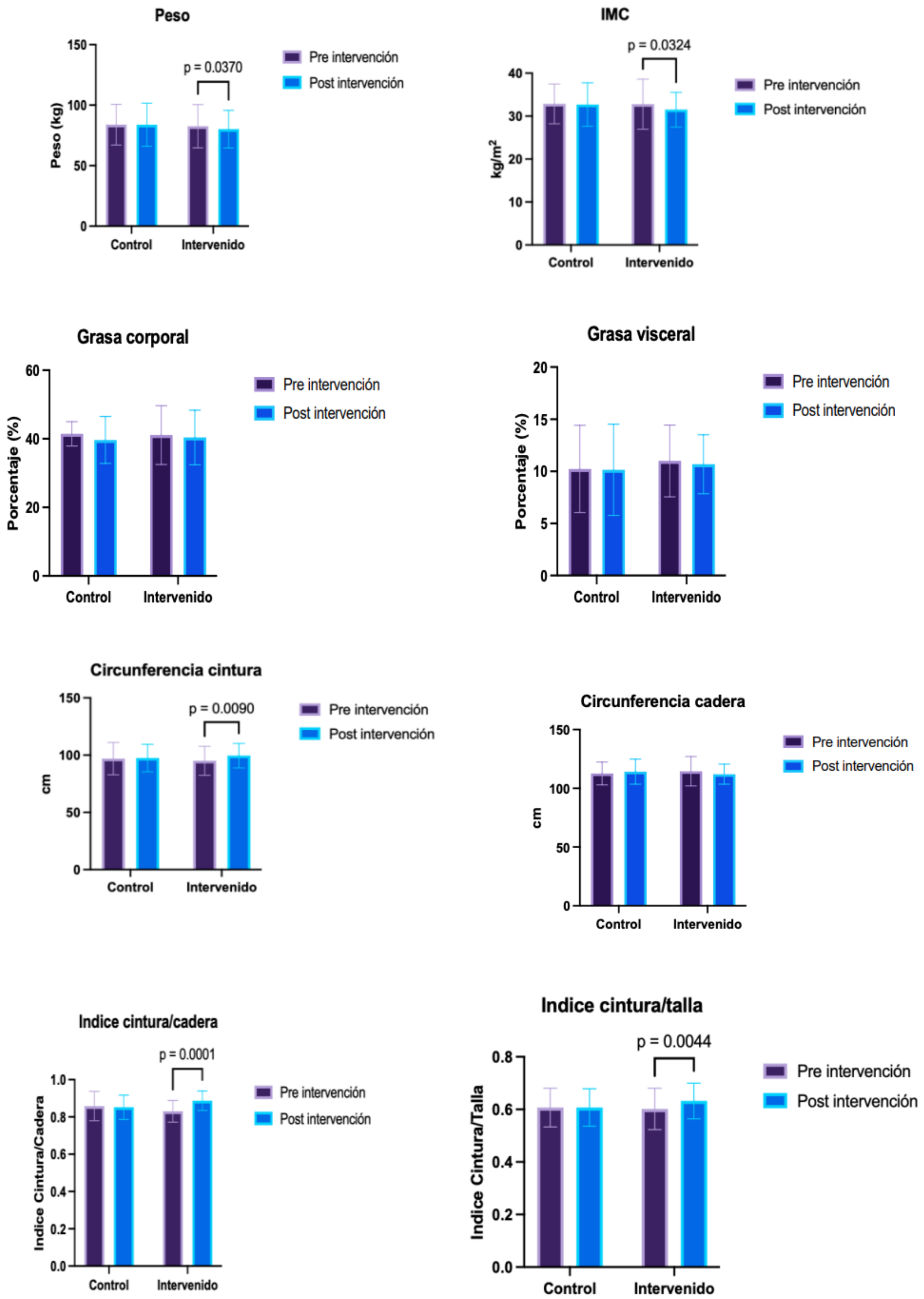

Figure 1. Comparison of anthropometric parameters (Weight, BMI, Body Fat, Visceral Fat, Waist Circumference, Hip Circumference, Waist/Hip Ratio and Waist/Height Ratio) between the control and intervention groups before and after the intervention

Table 2. P values obtained in the analysis of the anthropometric parameters of groups 1 and 2

Parameters	Group 1 Intervention DMM Pre and post intervention	Group 2- Usual Diet Control Pre and post intervention	Group 1 vs Group 2 Pre	Group 1 vs Group 2 Post
Weight	p=0.0370	p=0.921	p=0.8399	p=0.5742
BMI	p=0.0324	p=0.7945	p=0.9764	p=0.5326
Waist circumference	p=0.0090	p=0.7484	p=0.6937	p=0.6623
Hip circumference	p=0.0658	p= 0.2964	p=0.6439	p= 0.5763
Waist-to-size ratio	p=0.0044	p=0.9942.	p=0.8482	p=0.3649
Waist/hip ratio	p=0.0001	p=0.662	p=0.2281	p=0.0797
Body fat percentage	p=.0.5185	p=0.1379	p=0.8315	p=0.8231
Visceral fat	p=0.2788	p=0.8079	p=0.5824	p=0.7024

Table 3 shows the variations presented in the biochemical parameters before and after the intervention. In the DMM intervention group, glycemia decreased by 12.5 %, insulin and HOMA index by 62.5 %, glycosylated hemoglobin decreased by 43.5 %. Triacylglycerols and total cholesterol decreased in 68.75% of the population. As for lipoproteins, HDL increased in 50% of the interventional population, LDL decreased in 68.75% of the group, VLDL in 62.5%. The atherogenic index decreased by 75% and Interleukin 6 (IL-6) was reduced in 100% of this population.

Table. 3. Percentage of participants with variations in biochemical parameters after the intervention in group 1 and 2

Biochemical parameter	Group1 DMM Intervention	Group 2 Usual Diet Control
Blood glucose	12.5 %	30.76%
Insulin	62.5 %	61.53%
HOMA Index	62.5 %	53.84%
Glycosylated hemoglobin	43.5 %	15.38%
Triacylglycerides	68.75%	69.23%
Total cholesterol	68.75 %	46.15%
HDL	50% increased their values	69.23% increased their values
LDL	68.75%	53.84%
VLDL	62.50 %	69.23 %
Atherogenic Index	75%	76.92%
Interleukin 6	100 %	53.84%

Figure 2 shows the results of the Fisher LSD test for glucose, insulin, HOMA index, glycosylated hemoglobin, triglycerides, cholesterol in the control and intervention groups before and after the intervention. Figure 3 shows the comparison of the Fisher LSD test results for LDL, HDL, VLDL, atherogenic index, Interleukin 6 between the control and intervention groups before and after the intervention. Table 4 shows the p values for all the biochemical parameters analyzed, showing in group 1 the existence of a statistically significant difference between the values of glycemia and interleukin 6; however, group 2 shows the existence of a statistically significant difference in the values of glycemia, HDL, atherogenic index and interleukin 6, demonstrating the positive effects of nutritional education even without being accompanied by a dietary plan.

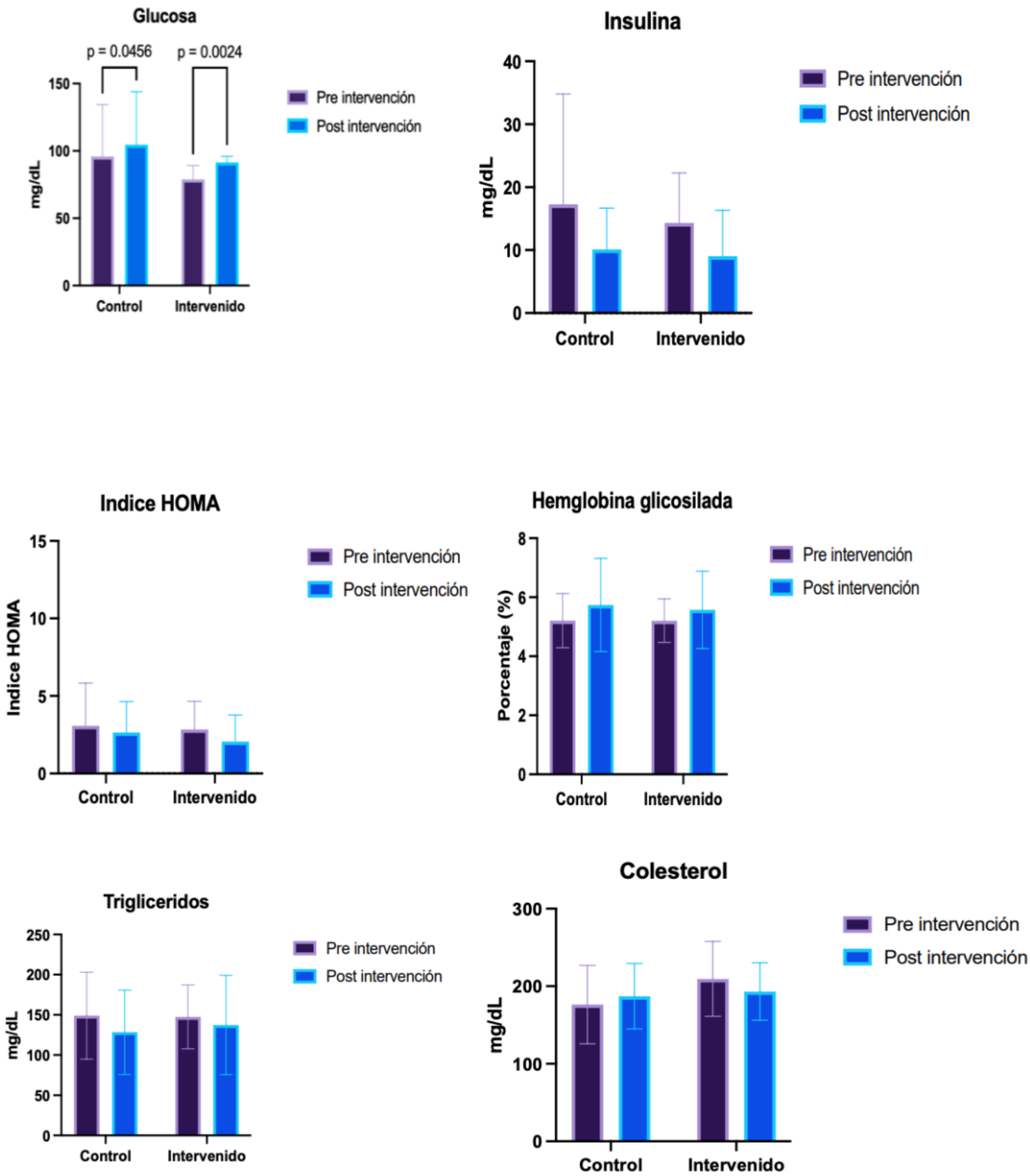

Figure 2. Comparison of biochemical parameters (glucose, insulin, HOMA index, glycosylated hemoglobin, triacylglycerides, cholesterol) between the control and intervention groups before and after the intervention

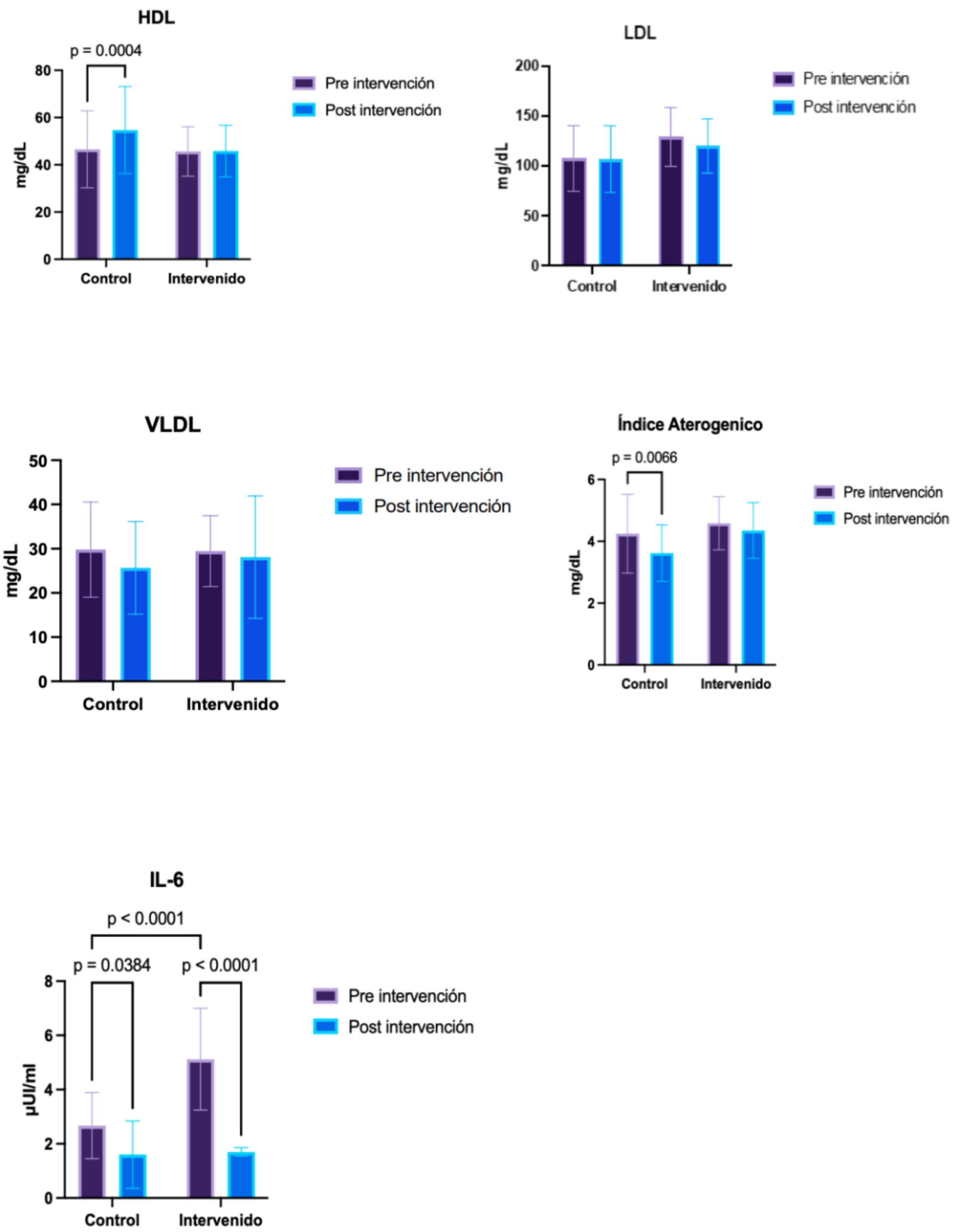

Figure 3. Comparison of biochemical parameters (LDL, HDL, VLDL, Atherogenic Index, Interleukin6 (IL6)) between the control and intervention groups before and after the intervention

Table 4. P values obtained in the analysis of the biochemical parameters determined in the intervention and control groups

Parameters	**Group 1 Intervention DMM Pre and post intervention**	**Group 2 Control Usual Diet Pre and post intervention**	**Group 1 vs Group 2 Pre**	**Group 1 vs Group 2 Post**
Blood glucose	p=0.0024	p=0.0456	p=0.0954	p=0.1944
Insulin	p =0.158	p=0.0766	p=0.371	p=0.7413
HOMA Index	p=1.142	p=0.5855	p=0.3118	p=0.7507
Glycosylated hemoglobin	p=0.3255	p=0.2144	p=0.9973	p=0.725
Triacylglycerides	p=0.3257	p=0.0763	p=0.9607	p=0.6129
Total cholesterol	p=0.0814	p=0.2833	p=0.0588	p=0.7246
HDL	p=0.9181	p=0.0004	p=0.8604	p=0.1036
LDL	p=0.097	p=0.8909	p=0.077	p=0.2652
VLDL	p=0.5477	p=0.1051	p=0.9471	p=0.535
Atherogenic Index	p=0.2312	p=0.0066	p=0.3679	p=0.0516
Interleukin 6	p=<0.0001	p=0.0384	p= <0.0001	p= 0.8359

Figure 4 shows the comparison of the values of the DMM diet adherence questionnaire in the group that consumed this diet. There was a marked improvement in adherence after the educational nutrition intervention.

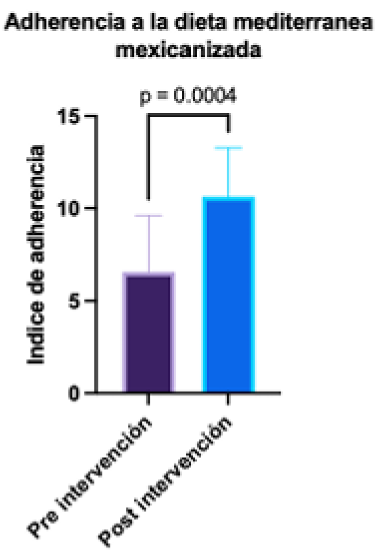

Figure 4. Comparison of DMM adherence values in the DMM intervention group before and after the intervention

Figure 5 shows a qualitative analysis of the dietary changes produced in the intervention group. A greater use of avocado oil for cooking, which went from not being used to being included in the consumption of 31.25% of the subjects, increased the use of olive oil for cooking and seasoning, as well as the consumption of fruits and vegetables daily, decreased the consumption of sugary and/or carbonated beverages daily and of commercial pastries daily. The consumption of red meat, hamburgers, sausages and cold meats was reduced and chicken was preferred, and the consumption of seafood and fish was increased. Nut consumption was incorporated into the daily diet in 56.25% of the participants, being one of the most important changes. Consumption of avocado and guacamole remained very high, as did daily consumption of legumes.

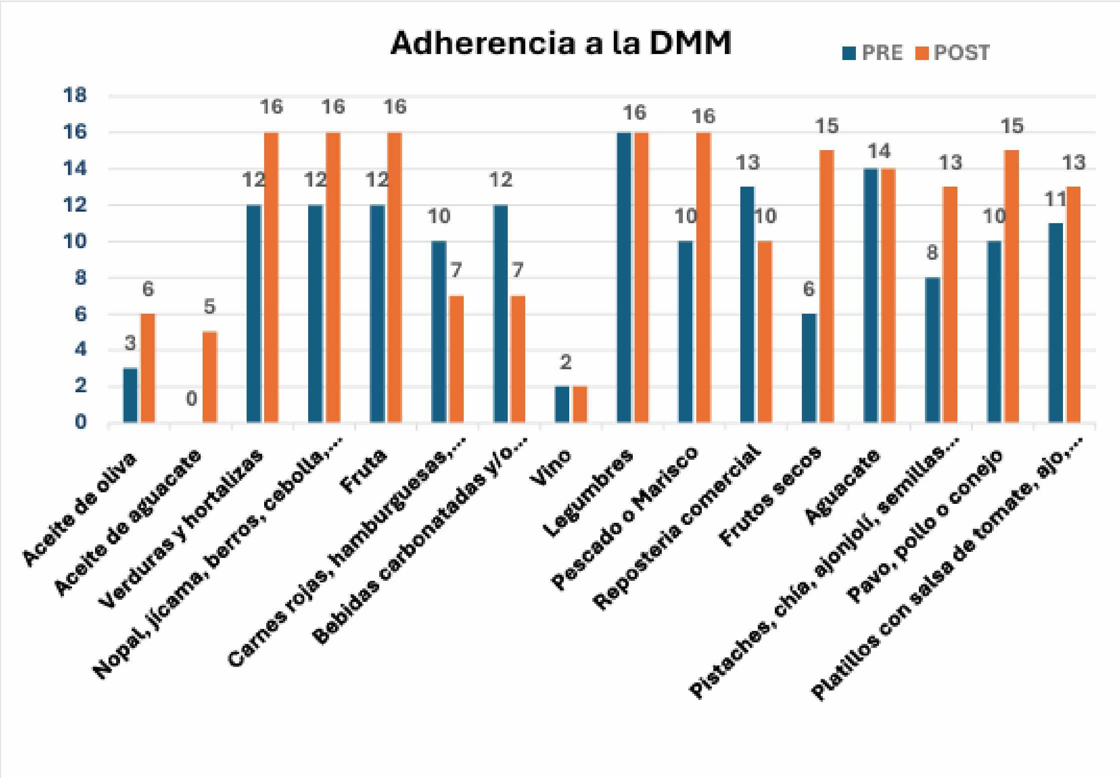

Figure 5. Dietary changes related to DMM adherence in the pre-intervention and post-intervention DMM intervention group

Figure 6 reflects the behavior of basic nutrition knowledge acquired in the sessions during the educational intervention in all participants. There was an increase in the level of nutritional knowledge in all subjects regardless of the group to which they belonged in the study.

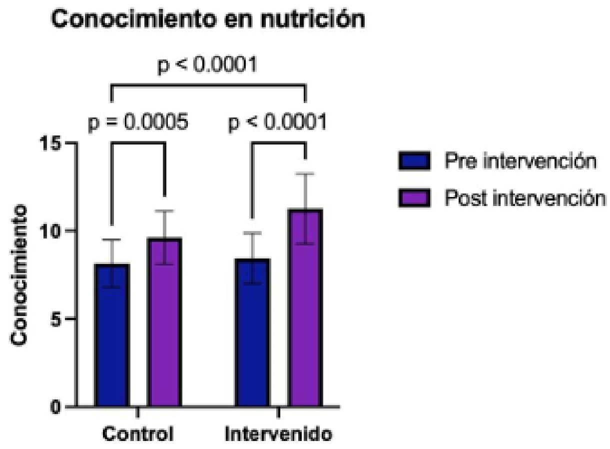

Figure 6. Comparison of the acquisition of basic nutrition knowledge before and after the intervention in the DMM intervention and DH control groups

We can comment that in group 1 with the intervention, 100% of the members increased their score in the post-intervention questionnaire, also the scores achieved were of higher value as well as the difference in the number of points obtained in the pre and post questionnaires when compared to group 2 control with habitual diet where 84.61 % of the subjects increased their score. We can affirm that the combination of the application of this DMM dietary strategy with a custom-designed plan and nutritional counseling educational sessions resulted in greater awareness and adherence to the dietary strategy, facilitating weight loss and a decrease in comorbidities. In the control group with a habitual diet, receiving nutritional counseling also had a positive influence on the results, but to a lesser extent than in the intervention group.

During the study, constant communication was maintained, as well as support by telephone and in the individual and group sessions, where existing doubts were clarified, which led to an approach that favored effective support.

Discussion and Conclusions

The Mediterranean diet is inversely associated with adiposity, the risk of type 2 diabetes and cardiovascular disease (6). The success of this diet is due to the synergy of its components and not the effect of a single individual food or nutrient. The Mediterranean diet has been associated with a better metabolic state due to its correct omega 3: omega 6 ratio, as well as its high content of fiber, antioxidants and polyphenols with anti-inflammatory properties (7). López Olivares et al. proposed that a better body composition of the individual is associated with a greater adherence to the Mediterranean diet and a better physical, mental and quality of life (19). Bastías et al. showed that participants with a low consumption index had a higher risk of obesity and higher anthropometric values, which is consistent. In individuals who consumed it frequently, the loss of body weight was greater, as well as the decrease in visceral ectopic obesity (20). According to the results of Bastías et al; in our study we were able to achieve a reduction in most of the anthropometric parameters of the group with DMM, due to the consumption of plant foods with low energy density and low glycemic load, which favors weight loss, as well as the high amount of fiber contained in the predominant foods, which leads to increased satiety. Estruch et al. in their study found that this diet is more effective for weight loss than other low-carbohydrate or low-fat diets (21). According to Rinott et al the Green-MED diet led to the greatest reduction in body weight, followed by the Mediterranean diet and the normal diet. These MED and Green-MED diets improved cardiometabolic markers, including Framingham risk, body weight, blood pressure, HOMA-IR, and plasma leptin (22).

The present DMM study contributed to promoting a decrease in body weight of more than 4% among the participants, which was present in 37.5% of the intervention group. Di Rosa et al. state that body weight loss of close to 5% can improve overall health (23) 5% can improve overall health (23). This author demonstrated that healthy weight is considered a risk modifier and has favorable effects on blood pressure, glucose metabolism, and cardiac and vascular problems. DMM in this study decreased BMI in 75 % of the members and reduced waist circumference in 25 % of the members of the intervention group. Sahrai et al. reported a positive relationship between high glycemic index of foods, high BMI and large waist circumference size in Mexican women, showing that greater adherence to the Mediterranean diet is associated with smaller waist circumference (24); these results are consistent with our findings.

The pathogenesis of cardiovascular diseases that are associated with obesity begins before the actual cardiovascular event, which detonates as the alarming event. It is important to emphasize the need to act preventively in anticipation of health damage. Clinical assessment of body fat distribution is very important. When there is an increase in central or visceral abdominal fat, it is necessary to detect the alteration of biochemical and clinical disorders that are completely related. These include insulin resistance, type 2 diabetes mellitus, arterial hypertension and ischemic heart disease. When we evaluate abdominal fat by anthropometry it guides us to look for the presence of dysglycemia which is caused by insulin resistance or beta cell dysfunction or both. In the present study, these parameters were evaluated and cases were detected that urgently needed professional help and nutritional guidance, which were referred for review by an internist and endocrinologist. Montemayor et al. commented that increased waist circumference is related to visceral fat accumulation, which causes hepatic inflammation, oxidative damage and hepatic steatosis (25). Adherence to the DMM allowed the reduction of the waist-to-hip ratio (WHR), body fat and visceral fat, which was determined by the high consumption of fiber, as well as by the knowledge of nutrition acquired through nutritional education, which allowed improving the selection of foods and their combinations, reducing the consumption of ultra-processed foods, which coincides with what has been reported in the literature by Bauce et al (26) and other studies (20,23,24).

The Mexicanized Mediterranean Diet (MMD) in the intervention group decreased glycemia, Insulin, HOMA index, and glycosylated hemoglobin. Vitale et al. related that the 8-week consumption of the traditional Mediterranean Diet improved post-meal glucose and insulin responses and increased the insulin sensitivity index, due to the effect of viscous dietary fiber that causes a delay in carbohydrate digestion and lower glucose spikes, coincides with our results (27). Zatterale et al. reported that high adherence to the Mediterranean Diet is associated with a lower risk of type 2 diabetes mellitus, showing an improvement in HbA1c concentrations and lipotoxicity (28). Paz Graniel, et al. reported that high adherence to the Mediterranean Diet had a beneficial effect on lipoprotein profile and glucose, due to the effect of omega-3 acids that can reduce lipolysis in adipose tissue and thus the outflow of free fatty acids into the circulation decreasing insulin resistance (29). Huo et al. report that the Mediterranean diet improves metabolism in individuals with diabetes (30). Salas et al point out that the Mediterranean diet enriched with extra virgin olive oil or nuts can help subjects at high risk of cardiovascular disease due to its high content of unsaturated fatty acids, fiber and polyphenols with synergistic action to counteract inflammatory and oxidative stimuli, decreasing the atherosclerotic process and the progression of diabetes. (31). The Mediterranean Diet is high in vitamins E and C, minerals such as magnesium and potassium that control blood pressure, improve endothelial function and insulin sensitivity, as well as reduce oxidative stress and inflammation. All these properties together result in a less atherogenic profile in subjects who consume it and a reduced risk of diabetes (31).

The levels of the different types of lipids were also modified in this intervention. The Mexicanized Mediterranean diet contributed to decrease the concentration of triacylglycerides, as well as total cholesterol and LDL, coinciding with the report by Bastías et al. that suggests the cardioprotective role of the Mediterranean diet (20)(32). Furlan et al. reported that healthy subjects consumed for 6 days a hyperlipidemic diet where butter was replaced by avocado oil extracted from the pulp and showed an improvement in the postprandial profile of insulin, glycemia, total cholesterol, low density lipoproteins, triglycerides and inflammatory parameters, such as C-reactive protein (CRP) and interleukin-6 (IL-6) (14). He demonstrated that avocado pulp oil from Mexican variants exhibits anti-inflammatory activity by inhibiting cyclooxygenase enzymes in a manner similar to ibuprofen. Damasceno et al. proposed that participants assigned to consume the Mediterranean Diet supplemented with 30 g of mixed nuts per day reduced the number and size of LDL particles, as well as increased HDL concentrations after the 1-year intervention. These results are linked to the LDL-lowering effect of nuts; in our intervention with DMM, nut consumption increased, which could be related to the LDL concentrations determined (32). Paz Graniel et al reported that the use of this diet reduced the size and quantity of LDL, a result that coincides with ours (29). Schwingshackl, L. et al. suggest that the Mediterranean Diet produces changes in markers of inflammation and endothelial function, including reduction of C-reactive protein, interleukin-6 and flow-mediated dilatation (33). In the present study, IL-6 values decreased in 100 % of the members of the DMM intervention group.

This intervention with DMM involved the delivery of the personalized nutrition plan and its combination with nutrition education allowed adherence to DMM to increase considerably between the two measurements. Bastías et al. report that a high rate of adherence to the Mediterranean Diet leads to metabolic benefits in people with obesity. If adherence to this dietary pattern is greater, the lipid profile improves as well as endothelial function, and insulin resistance decreases. The stability of these markers leads to a lower proinflammatory state and consequently to a lower BMI (20). Navarro et al demonstrated the existence of a high level of adherence to DM in adult university students in Murcia at the same time as a change in eating habits. Nursing students consumed more than one serving of vegetables per day and Food Science and Technology students consumed more than one piece of fruit per day (34). Mancini et al. reported the broad impact of the Mediterranean Diet on health, these authors suggest that adherence to the DM is associated with a 50% lower risk of developing metabolic syndrome, in addition to achieving an increase in biomarkers associated with healthy aging and reducing the risk of mortality by 20 years (35). In their study, López Olivares et al. showed that subjects with greater adherence had better anthropometric profiles, physical conditioning and even mental health (19). In our study we demonstrated that if the population identifies the need to eat healthily it will be easier for them to adhere to a particular dietary strategy because they recognize that it is positive for their health. Mancini et al. proposed that to achieve significant weight loss and increase the likelihood of clinically producing results, lifestyle modification through diet, behavioral therapy, and physical activity should be undertaken (35). It is worth mentioning that in our study there were very important qualitative changes such as the use of avocado oil for cooking, the use of olive oil, and an increase in the consumption of fish and seafood and nuts. There was a marked decrease in the consumption of daily sugary carbonated beverages, red meat, hamburgers, sausages, cold meats, as well as daily commercial pastries. Changes in eating habits occurred as a result of nutritional counseling and awareness-raising, which demonstrates the feasibility of educational intervention whether or not it is accompanied by a dietary plan.

The Mexicanized Mediterranean Diet is used to fight obesity, but it is also related to the improvement of other health conditions. Mendiola M et al. reported the positive effect of DMM in their longitudinal study in Mexican children with ASD who consumed this type of diet for 4 months. There was a greater attachment to this type of food by making the parents of the children aware of the importance of its consumption, educating them in the preparation and setting of the dishes. From a nutritional point of view, this attachment enhanced an increase in vitamin D levels, fiber, omega-3 and folate intake, as well as an increase in linear growth. The children's behavior showed that crying and impulsivity were reduced, as well as obsession between meal times, and there was an improvement in sleeping hours (10).

In the present study, the educational nutritional intervention was an appropriate option that achieved good results, as has been the case in similar studies. Arauz et al. developed a multidisciplinary educational intervention in diabetic patients in an urban community in Costa Rica, with the intention of modifying their dietary practices. Nineteen adults were included in the intervention group and 17 in the control group that continued with their normal routine. The educational part was structured in thematic weekly sessions, a food pattern was developed and the appropriate amounts that obese patients could consume, and changes in the current diet were suggested based on questionnaires. The consumption of total fat, saturated fat and cholesterol was reduced, the consumption of fruits and vegetables was increased, and eating schedules were organized in the intervention group after the nutritional education. For the clinical evaluation, lipid analysis, glycemia and glycosylated hemoglobin were determined, decreasing their values, as well as BMI in the intervention group (38). Fretes et al. conducted a three-month school-based educational intervention to assess fruit, vegetable and fish consumption in Chilean preschool and school children and their families. Knowledge about healthy eating was increased through six 90-minute cooking workshops to prepare food at home using new technologies such as videos and photography. Surveys and food questionnaires were completed before and after the intervention. Parents and teachers had basic knowledge of nutrition, but dietary intake was still unhealthy. Increased consumption of fruits and vegetables, as well as fish, was achieved. It was shown that it is possible to change eating habits by working together with the participation of the family, teachers and students, where personal motivation helps to achieve the objectives (39). Another nutritional intervention implemented in public middle schools in Toluca, Mexico with adolescents aged 11-12 years, focused on active learning, not only in offering knowledge in Nutrition but also in achieving the development of competencies that modify their eating habits using the theory of protective motivation which favored the change of attitude and self-efficacy. They learned to select the right foods, portions and balance, and self-manage their menus to achieve a balanced diet without restrictions. A satisfactory result was achieved since it changed the attitude towards food, as well as produced an increase in the perception of risk. The results showed an increase in self-efficacy in normal weight and overweight/obese youth, although it turned out that the intervention time should be extended to 6 months or 1 year to achieve changes in the groups that lagged behind. The importance of health education demonstrated in this work how knowledge and active learning could change habits in a difficult population in terms of behavior management and convincing, such as adolescence (40). Montenegro et al. conducted a quasi-experimental study in which they evaluated knowledge about nutrition and food, nutritional status and food consumption in Chilean teachers and students before and after the intervention. The intervention included 9 educational sessions for teachers during 5 months on healthy eating topics. It was observed that there was a transfer of teacher/student knowledge; the students of the trained teachers showed a decrease in the consumption of unhealthy foods and an increase in knowledge. The nutritional status was not modified due to the short intervention time, although it was suggested to increase the application time and involve the family to enhance its effect (41). Fausto et al. conducted an educational intervention with mothers in a rural community in Jalisco, Mexico. The educational, food safety and physical activity aspects were developed. The educational intervention was participatory, promoting reflection on the most consumed foods and which should be avoided, the negative habits that should be changed and the existing positive habits that should be reinforced. It became evident that healthy habits can be adopted and maintained. The educational sessions were weekly 1-hour workshops during 6 months with topics such as labeling, menu preparation, portion calculation, hygienic food handling. There were positive changes in knowledge that were manifested in the consumption of certain foods and natural drinking water (42). Vega et al. proposed the implementation of a nutritional intervention for 4 months in teachers in training at the Complutense University of Madrid, where they applied questionnaires on the knowledge present in the dietary guides and breakfast habits in week 1 of the course and in week 14 to evaluate the knowledge acquired during the intervention. Statistically significant variations were presented in terms of knowledge acquired about Nutrition and in terms of breakfast characteristics (43). A descriptive cross-sectional study was carried out involving 120 university students between 18 and 30 years of age from the University of San Luis in Argentina. Their objective was to evaluate the consumption of foods containing prebiotics and probiotics and their effect on metabolic syndrome risk markers. Anthropometric measurements were taken, as well as biochemical markers such as glycemia, total cholesterol, HDLc, LDLc, triglycerides and VLDL. Consumption of prebiotics and probiotics was assessed using a food frequency questionnaire and Inulin intake in participants was calculated according to average inulin content values in different plant species. It was shown that students who consumed prebiotics regularly had lower BMI and weight than those who did not consume them, in addition to lower levels of glucose and total cholesterol (44).

Nutritional and educational interventions at any level can help slow the progression of obesity and related diseases, and can raise awareness of the need to practice a healthy and active lifestyle with proper nutrition and physical exercise, aspects to be taken into account when implementing these primary strategies. It is also a key factor to consider the time required to achieve the goal of body weight loss. Generally, if this is not taken into account, overweight or obese people can become demotivated and abandon the nutritional protocol. A real and achievable goal must be set, supported by the creation of lasting habits over time, thus bringing about lifestyle changes that can be sustained, in unison with healthy eating.

The Mexicanized Mediterranean Diet (MDM) proved to be a successful and feasible option to prevent and treat overweight and obesity in the population studied. The Mexicanized Mediterranean diet had a positive effect on body composition and improved anthropometric and biochemical parameters. This type of feeding caused a decrease in the totality of anthropometric parameters in more than 25% of the members of the group intervened with DMM and in the biochemical parameters in more than 12.5% of these subjects. The educational intervention used in conjunction with the DMM plan contributed to improving the population's food culture and adherence to the proposed food plan. This strategy effectively promoted habit change, which can extend its duration and increase the level of knowledge and awareness of the population. The educational intervention increased the level of nutritional knowledge in all participating subjects.

Acknowledgments

University of Monterrey

Conflict of interest

The authors declare that there are no conflicts of interest in the conduct of this study

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