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Effects of a Community-Based Intervention on the Lifestyle and Health of People at Risk of Type 2 Diabetes in Benin

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Abstract

Introduction: Worldwide, the prevalence of type 2 diabetes (T2D) is increasing at an epidemic rate. The objective of this study was to measure the effects on lifestyle intervention in subjects at risk of T2D in a West African country. **Methods:** This study involved Beninese adults at risk of T2D randomly selected from 2 groups of villages: control villages and villages exposed to nutrition education, cooking demonstrations and physical activity sessions. Anthropometric, clinical, and biological measurements were taken in both groups at the beginning and end of the intervention, which lasted 12 months. The paired sample t-test was used to assess the effect of the intervention on the lifestyle of people at risk of T2D. **Results:** After 12 months of exposure to nutrition education, cooking demonstrations and physical activity sessions in the intervention villages, the mean body mass index, waist circumference, body fat percentage, blood glucose, triglycerides, total cholesterol and amount of alcohol consumed per week had significantly decreased. Conversely, the mean intensity of physical activity and food consumption score had significantly increased. In the control group, 5.6% of the people at risk developed to diabetes. The relative risk was RR = 0.20 [0.14 - 0.56]. **Conclusion:** The intervention significantly improved metabolic indicators, intensity of leisure activity and dietary score. We suggest larger studies to better assess the effect of community-based interventions on the lifestyle and health of people at risk of T2D in Africa.

Keywords

Effects, Primary Prevention, People at Risk of Type 2 Diabetes, Benin

1. Introduction

Type 2 diabetes mellitus (T2D) results from a combination of genetic and environmental factors. While genetics have some influence on the onset of diabetes, it is mainly environmental factors, particularly lifestyle habits, that will determine its early onset. Indeed, lifestyle habits characterized by an unbalanced diet (too rich in fat, sugar and salt, and poor in micronutrients) coupled with low levels of physical activity are responsible for the excess weight and obesity, which in turn will promote the onset of the disease [1] [2]. The International Diabetes Federation (IDF) estimates that there will be 36.5 million diabetic patients in low and middle income countries by 2045 [3]. Meanwhile, their health structures have not been sufficiently developed to allow the adequate management of the disease. In addition, preventive public health measures to contain its growth are slow to be implemented. Africa continues to bear the heavy burden of communicable diseases, to which is further added the economic burden of diabetes on patients, households and health care systems.

Regular physical activity combined with a healthy diet improves glycemic and lipid profiles [4], thus restoring the health of at-risk or prediabetic people and delaying or preventing the onset of T2D [5] [6]. However, the few lifestyle interventions carried out in Africa [7] [8] were not given any follow-up. Moreover, a systematic review of the past decade in Africa [9] has shown that no intervention has combined nutrition education, cooking demonstrations and physical activity sessions in people at risk of T2D with an active follow-up. In view of the epidemic increase in the prevalence of T2D in Africa, there is an urgent need to promote interventions to prevent the disease from continuing to progress, especially since infectious diseases still persist in the same regions. The objective of this study was to measure the effects of an intervention that combined physical activity, cooking demonstrations and nutrition education sessions in subjects at risk of T2D in a West African country. This intervention is part of the primary prevention of T2D of the Prévention du Diabète au Bénin (PreDiBe) Project in collaboration with the World Diabetes Foundation in the Department of Borgou, where the prevalence of diabetes is high compared to other Departments in Benin.

2. Materials and Methods

2.1. Study Setting

The study took place in the municipality of Tchaourou located in the north-east of Benin, a West African country with a population estimated at 11,810,324 inhabitants in 2019. 51.2% of whom are women [10]. The municipality of Tchaourou is home to 268,787 inhabitants [11]. It covers an area of 7256 km^2, which constitutes 28% of the total area of the Department of Borgou and approximately 6.5% of the national territory [11]. Its health sector is characterized by a low rate of coverage throughout the municipality. This study is part of a "PreDiBe" Project initiated by the IRSP (Regional Institute of Public Health) of Ouidah and the WDF (World Diabetes Foundation). The municipality's main activities are the cultivation of food crops (corn, sorghum, rice, cowpeas, soybeans, groundnuts, voandzou beans, yams, cassava) and especially cash crops (cotton, cashew nuts, shea nuts) [11]. The epidemiological diagnosis carried out in 2014 in the Departments of Alibori and Borgou [12] revealed high blood pressure in 31.10% of the population and excess weight in 60.24%; a prevalence of alcohol consumption of 30.36%, a tobacco use rate of 20.01% and a rate of physical inactivity of 39.29%.

2.2. Study Methods

Study type

This was a quasi-experimental before-after study with a control and a treatment group. A baseline survey was conducted **before** the intervention to collect socio-demographic data; anthropometric measurements; eating habits; lifestyle habits; knowledge, attitudes and practices regarding diabetes; fasting blood glucose and lipid concentrations. The same data were collected one year later **after** the nutrition education, cooking demonstrations and physical activity sessions. These data were collected in both the **treatment** and the **control** group.

Study population

The study participants were residents of the municipality of Tchaourou, aged 15 to 60 years, of both sexes and at risk of T2D. Those at risk were identified in a baseline survey using a FINDRISC (Finnish Diabetes Risk Score) questionnaire that took into account: age, BMI, waist circumference, practice of 30 minutes of physical activity, regular consumption of fruits and vegetables, presence high blood pressure, previous diagnosis of high blood glucose levels, and family history of diabetes. At the end of the questionnaire administration, a FINDRISC score was calculated for each subject. When the total score was greater than or equal to 12, the subject was identified as a person at risk of T2D [13].

Inclusion criteria

Each study participant met the following criteria:

- **Be between 15 and 60 years old**: Subjects over the age of 60 were not included as diabetes increases rapidly with aging, to which should be added any lifestyle changes. Conversely, subjects who are too young have a lower risk of T2D [14].
- **Be at risk for type 2 diabetes**: Subjects included in the study were those at risk for T2D as identified by their FINDRISC score.
- **Have had a fasting capillary blood glucose test with a value of less than 1.26 g/l** (to make sure that no diabetics were included in the study).
- **Be apparently healthy** (absence of clinical signs of diabetes and its complications; absence of chronic diseases such as hypertension, cancer or respiratory infections in their terminal stages).
- **Have resided permanently in the study area for at least 6 months**: It was important that all participants have been permanent residents of the study area for at least 6 months to ensure their integration into the living environ-

ment and lifestyle and also to ensure their presence at all meetings and thus minimize the risk of losing them to follow-up.

Non-inclusion criteria

The following were excluded from the study:

- **Pregnant and/or breastfeeding women**: The various changes in their physiological condition and eating habits could skew the survey data.
- **Those with medical conditions preventing the administration of questionnaires or the taking of measurements** even though they met the inclusion criteria.
- **Individuals who did not consent to participating in the study** despite meeting the inclusion criteria.

2.3. Sampling Method and Technique

The probability sampling method was used in this study. The subjects were selected from the list of at-risk individuals found in the 2 groups of villages surveyed using simple random sampling without replacement.

The sample size for this study was determined using the Lemeshow *et al.* sample size calculation formula that takes into account 2 independent populations (1 treatment group and 1 control group) [15]:

$$n = 2\sigma^2 \frac{\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{\left(\mu_1 - \mu_2\right)^2} = 71.25$$

with:

- *Sample size of each group*: $\boldsymbol{n}$
- *Standard deviation of the mean waist circumference from a previous study in Benin*: σ **= 12 cm** [16]
- *Standard deviation at* 95%: $Z_{1-\alpha}$ **= 1.645**
- *Standard deviation at* 90%: $Z_{1-\beta}$ **= 0.842**
- *Mean waist circumference of the subjects at risk of T2D expected after the intervention in Tchaourou*: μ_1 **= 81 cm**
- *Mean waist circumference of the subjects at risk of T2D expected after the intervention*: μ_2

In 2016, a 9-month intervention based on lifestyle change and physical activity reduced the waist circumference of the subjects by 6.3 cm at a cardiovascular rehabilitation and prevention center in Montreal [17]. We hypothesized that, after our intervention, μ_1 would be reduced by 5 cm: *i.e.*, $\mu_2 = \mu_1 - 5 = 76$ **cm**.

By increasing the sample size by 10% to cover dropouts and those lost to follow-up during the study, the minimum sample size reached 78 per group. We rounded up to **90 subjects per group**.

Studies have shown that among the risk factors for T2D a large waist circumference is the best predictor of its occurrence [18]. For the present study, we used the mean waist circumference (μ_1) of subjects at risk of T2D from our preliminary survey in the municipality of Tchaourou to calculate the sample size ($\boldsymbol{n}$)

of each group.

The 90 subjects in each group were selected among the people at risk of T2D detected during the baseline survey using simple random sampling.

2.4. PreDiBe Project Interventions

The study focused on 2 groups of villages in the municipality of Tchaourou: a treatment group consisting of 4 villages (Tchatchou: 23; Tékparou: 22; Tchaourou centre: 23; Worogui: 22) and a control group consisting of 2 villages (Badekparou: 42; Kinnoukpanou: 48).

Treatment group

In the 4 treatment villages, subgroups of 8 to 10 participants were formed by affinity. The intervention group benefited from 6 nutrition education sessions followed by cooking demonstrations. Each education session was led by nutritionists trained for this purpose. During each session, the nutritionists used instructional sheets with well-defined objectives to develop educational themes. Each nutrition education session lasted 1.5 to 2 hours and was conducted in a guided discussion format. The goal was to reduce weight by decreasing the portions of cereals and starchy foods ingested, reducing fatty foods and promoting the consumption of fruits and especially of vegetables.

The nutrition education topics were:

- **Term 1**: Balanced plate
- **Term 2**: Identifying the appropriate portions of fruits and vegetables
- **Term 3**: Identifying the appropriate portions of cereals and tubers, proteins and dairy products
- **Term 4**: Food hygiene and pesticide contamination
- **Term 5**: Beverages (water/herbal teas/soft drinks/alcoholic beverages)
- **Term 6**: Lifestyle (tobacco use and alcohol consumption)

For the cooking demonstrations, the menus were based on local eating habits to ensure that the food was acceptable, accessible, available and adequate. The menus were the same in all the treatment villages each Term. Each week, the subgroups met to support each other, be motivated, interchange and discuss with nutritionists the difficulties in achieving the nutrition education goals. The leader of each subgroup, accompanied by a nutritionist, made home visits to motivate subgroup members to implement nutritional recommendations and perform physical activities.

Peer educators or nutritionists led 30-min sessions of moderate physical activity ***each day*** in subgroups of 8 or 10 at-risk subjects. These sessions took place at the homes of the peer educators. Vigorous group physical activity sessions were performed for 1 hour every Saturday at the local sports field. These ***weekly*** sessions started with 15 minutes of aerobic activity in short strides, followed by 40 minutes of continuous activity marked by peaks of effort of 1 minute every 5 minutes, followed by abdominal exercises, and ended with 5 minutes of stretching. These physical activity sessions were complemented by 1-hour long quick-paced group walks, on the first Saturday of ***each month***. The group physical activity sessions were led by sports teachers from the local high school. Contemporary local music was used to inspire and motivate during each physical activity session.

Control group

In the 2 control-villages, all at-risk subjects received general information on diabetes and its complications as well as advice on diabetes prevention measures. These subjects were provided their glycemic and lipid status (total cholesterol, HDL cholesterol, LDL cholesterol and triglycerides) at the beginning and end of the study.

2.5. Data and Sample Collection

A standardized questionnaire was administered to participants at the beginning and end of the intervention to collect socio-demographic data, eating habits, level of physical activity, tobacco use and alcohol consumption status. Anthropometric measurements were taken: weight, standing height, waist circumference, percentage of body fat and blood pressure. Following these measurements, blood samples were taken: 4 ml of blood in a dry, well-labeled 5 ml tube and 4 ml of blood in a 5 ml blood glucose tube. These blood samples were immediately placed in a cooler filled with ice packs and promptly transported to the laboratory at municipal health center. The blood samples were centrifuged, aliquoted into Eppendorf microtubes and stored at −20˚C before being transferred to the Public Health Laboratory of the Comlan Alfred QUENUM Regional Institute of Public Health (IRSP-CAQ) in Ouidah for biological measurements such as fasting blood glucose, total cholesterol, HDL cholesterol, LDL cholesterol and triglycerides.

In the treatment villages, support groups of 8 or 10 at-risk subjects each were formed. Quarterly follow-ups of these subgroups were then conducted. They received 6 terms of nutrition education sessions, each with a different theme. The same information was covered in each group. They also benefited from cooking demonstrations based on local foods and traditional meals that are low in fat, sugar and salt and high in fiber, vitamins, minerals and antioxidants. Three (3) nutritionists performed these various activities. They also made house calls and conducted weekly practice sessions with each group. The physical activity exercises were performed individually every day for 30 minutes and in groups weekly for 1 hour under the supervision of sports teachers. This monitoring lasted 1 year from August 2017 to August 2018.

2.6. Measurement of Study Variables

The ***dependent variables*** were the biological risk factors: blood glucose (Gly), blood pressure (BP), triglycerides (TG), total cholesterol (total-C), LDL cholesterol (LDL-C), HDL cholesterol (HDL-C), body mass index (BMI), waist circumference, body fat percentage (BF %).

The ***intermediate independent variables*** are the modifiable behavioral factors: dietary profile, level of physical activity, alcohol consumption status, smoking status.

The ***independent exposure variables*** were: participation in nutrition education sessions, participation in cooking demonstration sessions, participation in physical activity sessions as well as the duration of these sessions.

Biological risk factors

- **Glycemia (blood sugar levels)**: At the Public Health Laboratory of the IRSP-CAQ in Ouidah, the glucose oxidase method was used to measure the blood glucose levels in the plasma of subjects at risk of T2D fasting for at least 12 hours. The samples were analyzed using a Mindray BA-88A spectrophotometer (WR-47015295; made in China). In the present study, a fasting blood glucose level of 7.0 mmol/L (126 mg/dL) or higher was defined as T2D according to the WHO recommendations [19].
- **Blood pressure**: Blood pressure was measured with an OMRON M3 automatic digital blood pressure monitor (m3v4373504; made in Japan) with an accuracy of +/-3 mmHg. The measurements were taken after the participants were seated for 15 minutes. Two readings were taken 5 minutes apart. The average of these readings was then retained [20]. Both blood pressure measurements for each participant were taken by the same research team member. The WHO criteria for defining high blood pressure (hypertension) were used in this study, namely a systolic blood pressure ≥ 130 mmHg and/or a diastolic blood pressure ≥ 85 mmHg [21].
- **Lipid profile**: The blood samples collected from the participants were used to assess TG, HDL-C, total-C and LDL-C. The risk defining threshold values were: total-C > 2.4 g/l; LCL-C > 1.75 g/l; HDL-C < 0.35 g/l; and fasting TG ≥ 1.50 g/l [22].

The direct readings for TG, HDL-C and total-C were taken with the same spectrophotometer used to assess blood glucose. LDL-C was calculated using the following formula [23]:

$$\text{LDL-C} = \text{total-C} - \left(\text{HDL-C} + \frac{\text{TG}}{5}\right)$$

Anthropometric measurements

- **Weight**: The weight was measured on an empty stomach using a SECA E753 scale (made in Hamburg, Germany) with a maximum capacity of 150 kg and an accuracy of 0.1 kg. The participants wore light clothing with empty pockets when the measurement was taken [24]. The scale was calibrated daily before each series of measurements.
- **Height**: After weight measurement, the height of each subject was measured using a SECA stadiometer (height rod). The subjects were asked to stand on a flat surface with their feet together and with their buttocks and backs against the vertical rod. They lifted their chins so they could look straight ahead (Frankfurt horizontal plane) [25]. The sliding horizontal headpiece was lo-

wered to rest on top of their heads, then their height was read on the measuring rod to the nearest 0.1 cm.

- **Overweight**: The body mass index (BMI = weight/height^2) was the indicator used in this study to define the overall obesity of the study participants. A BMI between 25 and 29.9 defined overweight whereas a BMI ≥ 30 defined obesity [26].
- **Body fat percentage**: The body fat percentage was measured with a precision of 0.1% using a CAMRY EF-538 digital electronic impedance meter (made in China). The subjects were clothed in light clothing and barefoot. The body fat percentage was the index used to assess the body composition of the study subjects: the proportion of adipose tissue compared to that of muscle tissue.
- **Abdominal obesity**: The waist circumference measured to the nearest 0.1 cm with a flexible, non-stretchable measuring tape. It was placed midway between the lateral lower ribs and the iliac crests [27]. The IDF thresholds values [28] were used to detect all individuals at risk for abdominal obesity: 94 cm for men and 80 cm for women.

Modifiable behavioral risk factors

- **Eating habits**: The participants' eating habits were collected using a food frequency questionnaire. For each participant, the questionnaire documented the daily, weekly and monthly frequency of food consumption. The "health" foods were selected in view of the abundant documentation on their benefits: fruits, vegetables, nuts, pulses and fish [29]. The "health" food consumption score was calculated from the sum of the weekly frequency of consumption of these foods. The scores were then categorized into 3 groups: the tertiles low, medium and high.
- **Level of physical activity**: Information on physical activity was collected through a questionnaire based on WHO's questionnaire for physical activity surveillance. The intensity of physical activity was assessed according to the energy expenditure induced and the type of recreational activity. They were categorized into low, moderate and high intensity activities [30]. The average intensity, expressed in MET (Metabolic Equivalent of a Task), was calculated based on the intensity of the physical activity.
- **Alcohol consumption**: A questionnaire was used to gather information on alcohol consumption. The questions used were taken from the WHO STEPwise approach to chronic disease risk factor surveillance and were adapted to the context of this study. These questions identified drinking habits (frequency, quantity), type of alcoholic drink (wine, beer, distilled beverages). From the information collected, we determined the amount of alcohol consumed per week. We then calculated an alcohol consumption score taking into account the reported effects for moderate alcohol consumption in the literature [31].
- **Smoking status**: Data on tobacco consumption was collected using the questionnaire based on the WHO STEPwise approach to chronic disease risk factor surveillance [32]. The questions identified the various forms of tobacco

use as well as the consumption habits.

2.7. Data Analysis

The data were summarized and presented using tools of analytical and descriptive analysis. Before the intervention, the difference in averages between the control and treatment groups was calculated for each parameter. The independent samples t-test was used to confirm that the 2 groups were identical at the start.

After the implementation of the activities, we determined the effect of the intervention using the paired samples t-test. The data were analyzed using the software IBM SPSS Statistics 20.

2.8. Ethical Consideration

The protocol was approved by the Ethics Committee of the Ministry of Health of Benin. Participation in the study was conditional on each participant signing an informed consent form beforehand. Subjects who were identified as diabetics received nutritional counseling by trained nutritionists. They were referred to the district hospital for appropriate medical care. Each participant was reassured about the confidentiality of the data collected. During follow-up visits, study participants received general nutritional counseling to help reduce their risk of developing diabetes.

3. Results

- 91% of the beneficiaries used the new culinary practices learned during the cooking demonstration sessions;
- there was an 88% reduction in high-calorie meals in favor of vegetables;
- 81% of the beneficiaries practiced at least 150 minutes of physical activity per week;
- 80% of the beneficiaries participated in all the planned activities;
- 65% reduced their alcohol consumption; there was no significant change in the proportion of participants who used tobacco (62%).

The program beneficiaries' level of knowledge of diabetes (symptoms, complications and prevention) was assessed through a questionnaire. It increased from 32% at the start to 92%.

The relative risk (RR) of T2D 0.20 [0.14 - 0.56].

The characteristics of the participants in the treatment and control groups at the beginning of the intervention are presented in **Table 1**. The p-values and the confidence intervals around the differences in averages showed that there was no significant difference between the treatment group and the control group at the start of the study.

The evolution of Risk Factors in those at risk for Type 2 diabetes in the control group after 12 months of exposure to generic advice on the Prevention of Type 2 diabetes is presented in **Table 2**. The means of body mass index, waist

Table 1. Characteristics of people at risk at the intervention beginning.

Variable	Exposed (n = 90)	Control (n = 90)	IC 95%	P
	Average ± SD	Average ± SD		
Age	42.3 ± 5.9	43.10 ± 11.6	[−1.95; 3.34]	0.60
Score Wellness index	18.0 ± 6.3	18.12 ± 06.7	[−0.21; 0.24]	0.90
BMI	32.3 ± 7.8	30.77 ± 06.1	[−3.63; 0.51]	0.29
Waistline	100.8 ± 16.3	100.23 ± 12.2	[−4.77; 3.71]	0.80
PAS	144.7 ± 24.7	142.00 ± 21.7	[−9.53; 4.21]	0.50
PAD	90.5 ± 13.7	85.97 ± 15.7	[−8.66; 0.06]	0.50
%MG	33.3 ± 12.7	30.78 ± 11.5	[−6.97; 0.14]	0.06
Gly	01.2 ± 00.8	01.13 ± 09.0	[−0.04; 2.21]	0.12
TG	01.5 ± 00.2	01.51 ± 00.2	[−0.03; 0.60]	0.50
HDL-C	00.4 ± 00.1	00.41 ± 00.1	[−0.06; 0.04]	0.09
Chol-T	02.0 ± 00.4	02.10 ± 00.4	[−0.04; 0.16]	0.24
Chol-LDL	01.2 ± 00.3	01.18 ± 00.3	[−0.14; 0.86]	0.08
Sore consumption Health Food*/Week	12.7 ± 06.3	15.03 ± 12.1	[−0.21; 5.45]	0.07
Amount of alcohol (g)/week	73.65 ± 14.8	66.36 ± 12.2	[−9.28; 8.85]	0.41
Intensity leisure activity (MET)	10.03 ± 3.2	10.57 ± 3.5	[−0.79; 1.91]	0.41
Use Tobacco (%)	50.0	53.0		0.65

T Test for independent samples: no significant difference. *"Healthy foods" considered are foods that promote better health according to the literature [29].

Table 2. Comparison of risk factor averages in people at risk of T2D before and after 12 months.

Variables	Control group (n = 90)				Intervention group (n = 90)			
	Baseline data	Data after 12 months	Difference in means (CI 95%)	P	Baseline data	Data after 12 months	Difference in means (CI 95%)	P
	Mean ± SD	Mean ± SD			Mean ± SD	Mean ± SD		
BMI	30.77 ± 6.14	32.30 ± 4.85	1.53 (0.88 to 2.19)	**0.05**	32.33 ± 7.85	29.71 ± 4.87	−2.54 (−3.16 to −1.92)	**0.001**
Waist circumference	100.23 ± 12.22	104.43 ± 12.05	4.20 (3.88 to 4.51)	**0.001**	100.76 ± 16.33	95.26 ± 11.08	−5.50 (−6.56 to −4.43)	**0.001**
SBP	144.00 ± 21.71	145.65 ± 22.69	1.63 (0.26 to 3.01)	**0.02**	144.66 ± 24.73	145.64 ± 22.65	−0.98 (−0.26 to 3.01)	0.07
DBP	85.97 ± 15.71	87.70 ± 12.49	1.50 (1.41 to 2.05)	**0.001**	90.51 ± 13.75	89.83 ± 12.49	−0.68 (−0.91 to 2.05)	0.24
BF %	30.78 ± 11.49	32.28 ± 9.47	2.41 (0.53 to 2.48)	**0.03**	33.29 ± 12.68	30.60 ± 9.47	−2.70 (−4.04 to −1.33)	**0.001**
Gly (blood glucose)	1.13 ± 0.09	1.22 ± 0.08	0.08 (0.07 to 0.09)	**0.001**	1.12 ± 0.8	1.05 ± 0.10	−0.07 (0.05 to 0.08)	**0.001**
TG	1.51 ± 0.16	1.63 ± 0.15	0.12 (0.11 to 0.13)	**0.001**	1.50 ± 0.15	1.28 ± 0.15	−0.21 (−0.25 to −0.18)	**0.001**
HDL-C	0.41 ± 0.09	0.42 ± 0.03	0.01 (−0.02 to 0.15)	0.87	0.43 ± 0.12	0.54 ± 0.03	0.19 (0.08 to 0.13)	**0.001**
Total-C	2.08 ± 0.35	2.07 ± 0.37	−0.01 (−0.02 to 0.04)	0.06	2.02 ± 0.37	1.97 ± 0.42	−0.04 (−0.06 to 0.02)	**0.001**
LDL-C	1.18 ± 0.26	1.20 ± 0.26	0.01 (−0.03 to 0.08)	1.38	1.21 ± 0.25	1.22 ± 0.29	0.02 (−0.03 to 0.04)	0.14

Continued

Score of health food* consumption/week	16.14 ± 12.08	15.03 ± 12.49	−0.21 (0.63 to 0.21)	0.32	12.75 ± 6.30	19.15 ± 12.33	6.40 (7.38 to 12.49)	**0.001**
Amount of alcohol (g)/week	73.46 ± 12.19	73.65 ± 12.22	0.18 (−0.76 to 0.38)	0.51	73.65 ± 14.76	60.35 ± 12.20	−0.13 (−7.19 to −0.09)	**0.03**
Intensity of leisure-time activities (MET)	10.53 ± 3.47	10.55 ± 3.52	0.22 (−0.08 to 0.53)	0.15	10.03 ± 3.17	18.28 ± 3.61	8 (8.51 to 16.20)	**0.001**
Tobacco use (%)	53	55		0.03	55	57		0.70
Incidence of diabetes	1/90	5/90			0%	0%		

*The "health" foods considered are those that promote better health according to the literature [29]. Paired samples t test.

circumference, fat percentage, systolic and diastolic blood pressure, blood sugar and triglycerides were significantly elevated after 12 months of theoretical health promotion intervention in people at risk of Type 2 diabetes in the control group.

Table 2 presents the changes in risk factors among the people at risk of T2D in the control group who received generic advice on T2D prevention for 12 months. The body mass index, waist circumference, body fat percentage, systolic and diastolic blood pressure, blood sugar and triglycerides averages are all significantly elevated after 12 months of theoretical health promotion intervention in the control group subjects. The changes in risk factors among the people at risk of T2D in the treatment group who participated in cooking demonstrations, nutrition education and physical activity sessions on a regular basis for 12 months. The mean body mass index, waist circumference, body fat percentage, blood glucose, triglycerides, total cholesterol and amount of alcohol consumed per week had significantly decreased. Conversely, the mean food consumption score and intensity of physical activity had significantly increased.

4. Discussion

The present study explored the effect of an intervention that combined nutritional education with physical activity for 12 months in people at risk for T2D. To our knowledge, no study to date has evaluated the effect of such an intervention in at-risk individuals with a control group in Africa [9]. We noted a significant improvement in behavioral risk factors and a significant decrease in modifiable biological risk factors after 12 months of exposure to nutrition education sessions, cooking demonstrations and regular physical activity. No loss to follow-up was recorded in this study where at-risk people were followed for a year. Though a few participants had missed some of the cooking demonstrations, physical activity or nutrition education sessions, 80% of the participants had attended all intervention sessions over the 12 months. At the end of the study, all participants were present and evaluated.

Data quality and validity

The probability sampling method was employed in this study with simple random sampling without replacement. A pre-test was performed to minimize loss of information and the risk of translation errors. Data collection was carried out with validated tools and interviewers were trained in their proper use. All these precautions were taken to minimize bias and thus improve the quality of the data and the internal validity of the results.

Effects obtained in the control group in the absence of interventions

The control group, which served as a reference for comparison with the group exposed to lifestyle interventions, showed a significant increase in risk factors such as body mass index, waist circumference, blood pressure, body fat percentage, blood glucose and triglycerides after 12 months of intervention. After this period, 5.6% of the control group participants became diabetic. This result is close to that found by Bennasar-Veny *et al.* among prediabetic Spanish workers, 4.6% of whom became diabetic at the one year follow-up [33]. Several modifiable behavioral risk factors were found to be associated with modifiable biological risk factors [34]. Many studies have shown results of progression to diabetes among the control group subjects. For example, a 2018 study of people at risk of T2D in India selected with the Indian Diabetes Risk Score questionnaire reported a 17.1% progression to diabetes in the control group [35].

Obesity, especially abdominal obesity, is a key factor in the genesis of T2D [36]. The imbalance between food intake and energy expenditure over a more or less lengthy period of time plays a big role in the nutritional causes of this obesity. Carbohydrates are sources of energy substrates. Thus, when the food intake is too rich in carbohydrates (quantity and quality [37] [38], or quality [39]), these are stored due to lack of use (absence of physical activity). This storage is in the form of triglycerides, which contribute to abdominal obesity. This in turn triggers the metabolic disorder whose long-term consequences are, among others, the appearance of T2D. This means that a diet with a high glycemic index, low in fiber and high in certain fatty acids (saturated fats and trans fats) doubles the risk of diabetes [40]. Our results confirm the progression of at-risk individuals to diabetes if no practical action is taken to promote healthy lifestyles.

Effects obtained after 12 months in the group exposed to the sustained lifestyle interventions

The results of this study showed a significant reduction in body mass index, waist circumference, body fat percentage, blood glucose, triglycerides and total cholesterol in the group exposed to 12 months of primary T2D prevention sessions in the community. The results also showed an increase in the food consumption score and the intensity of leisure-time physical activity. The reduction in risk factors after the intervention indicates a beneficial effect which may be due to the intensity and regularity of the sessions as well as to the individual monitoring of study participants in groups and at home. The reduction in body fat percentage and waist circumference showed a significant decrease in abdominal obesity in this group. The improved diet quality contributed to this decrease. The 2015 study by Wrong *et al.* in New Zealand was in the same vein as the present study and reported similar results [41]. Abdominal fat is the surest predictive factor in the development of T2D [42]. This abdominal adipose tissue is responsible for the inflammation that underlies metabolic diseases such as T2D [43].

Moreover, only one participant developed diabetes in the group exposed to 12 months of lifestyle interventions. Studies have shown a significant decrease in the prevalence of diabetes in the treatment group compared to the control group [44]. Several studies have also shown that appropriate lifestyle interventions have delayed or prevented the onset of T2D in prediabetic people [45]. The study by Dagogo-Jack *et al.* also reported reversibility in prediabetics after an intensive 6-month intervention [46].

One study reported that 90% of diabetes cases could be attributed to environmental factors and could therefore be prevented [47]. Food is a major environmental factor. Fardet *et al.* reported that a balanced diet rich in unrefined/minimally processed plant-based foods which have preserved their initial food structure as well as a nutritional density high in protective bioactive (fiber, minerals, vitamins, polyphenols and carotenoids) protect against T2D [48]. The present study included cooking demonstrations that showed examples of food processing and how to design balanced plates rich in minerals, vitamins and dietary fibers. This would partly explain the reduction of the study participants' biological risk factors since micronutrients play a key role in the management of T2D [49]. In addition, physical activity improves the glycemic [50] and lipid profiles of prediabetic people [51].

The results of the present study also showed a significant decrease in triglycerides and total cholesterol and an increase in HDL cholesterol. The fact that none of the treatment group participants became diabetic could be explained, firstly, by the intensity and the regularity of the physical activities (monthly, weekly and daily) since several studies [52] have shown that the regular practice of physical activity helps burn fat and maintain a healthy weight, which means the absence of obesity and, consequently, the failure to develop T2D. Secondly, consuming lots of vegetables reduces the intake of high calorie meals and improves the lipid profile [53]. This may explain the improved lipid profile of the at-risk individuals in the treatment group. The results also show that the risk factors for T2D are reversible to a significant degree in subjects at high risk for T2D. These results confirmed those of the 6-month lifestyle intervention in Saudi Arabia among obese adult subjects whose glycemic and lipid profiles were improved [54]. In the present study, there was no significant decrease in average blood pressure. This could be because the practice of chewing tobacco is a cultural behavior in the study area. Several studies have indicated an association between tobacco use and high blood pressure [55].

The economic burden of T2D is exorbitant. The International Diabetes Federation (IDF), Ninth Edition, 2019 reported that the global cost of diabetes will rise to 825 trillion in 2030 and 845 trillion in 2045 [56]. Interventions to delay the onset or complications of diabetes have had an effective cost-benefit. Studies have shown that vascular disease increased the cost burden for individuals with T2D. The costs of care of T2D patients with vascular disease were largest within the first year following diagnosis and persisted for at least 7 additional years. On the other hand, the costs of care of T2D patients without vascular disease were significantly lower compared to non-diabetic control patients [57]. Primary prevention interventions to reduce the prevalence of T2D in at-risk individuals are important, especially in low-income countries, in view of the heavy burden already placed on them by infectious diseases.

Another major result showing the effect of the intervention is that the relative risk RR of diabetes is equal to 0.20 [0.41 - 0.56]. This value is less than 1 with a confidence interval that excludes 1, meaning that the intervention has a protective and beneficial effect on those at risk for type 2 diabetes. In other words, the intervention reduced the risk of developing diabetes by 20%.

Several studies have shown the protective effects of primary prevention interventions in people with prediabetes or at risk of T2D. In Qatar, in 2020, Taheri *et al.* reported the beneficial effects of a primary prevention intervention in people with new-onset diabetes (lower calorie diet combined with physical activity for 12 months). This study showed a significant improvement in cardiometabolic markers with a diabetes remission rate superior to 60% among participants [44]. Dagogo-Jack *et al.* conducted a primary prevention study (reduction of high-calorie meals and practice of 180 minutes of physical activity per week) among prediabetic people at high risk of T2D, namely African-Americans and European-Americans with a parental history of T2D. The primary outcome of this study was the reversal of prediabetes and the restoration of normoglycemia [46]. These results confirm the beneficial and protective effects of primary prevention interventions found in the present study.

5. Conclusion

The early management of people at risk of T2D is beneficial to households and health care systems with attractive cost effectiveness. This study is one of the first in Africa to combine nutrition education sessions and physical activity with sustained support of beneficiaries at risk of T2D. The results were satisfactory. The intervention significantly improved metabolic indicators such as body mass index, waist circumference, fasting blood glucose, HDL cholesterol, total cholesterol, intensity of leisure activity and dietary score. We suggest larger studies to better assess the effect of interventions on the lifestyle of people at risk of T2D in Africa.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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