Risk analysis and effect of physical activity on type 2 diabetes in a population of Oujda-Eastern Morocco following a physical activity program

Corresponding Author: Amal Azdimousa[1], Abdellatif Maamri[1]

1 Laboratory of the improvement of Agricultural production, Biotechnology and the Environment, Faculty of Sciences, Mohammed First University, BP 717, Oujda, 60000, Morocco
E-mail address: azdimamal@gmail.com

KEYWORDS
physical activity
diabetes
lipid profile
risk analysis

ABSTRACT:
Introduction: Among the subjects of concern is type 2 diabetes, and the effect of physical activity (PA) on their diabetic balance stands out. Thus, it is known that physical activity increases the effectiveness of insulin by improving the sensitivity of body tissues to its action; it generally allows for better control of glycemia. In addition to the advantages mentioned, the regular practice of physical activity even allows one to normalize glycemia and thus to avoid the use of medication or, if necessary, to reduce the dose.**Objectives**: The main objective of the present study is to evaluate the impact of physical activity on the management of type 2 diabetes as a function of time and to analyze the risk factors associated with it.**Methods**: This is a prospective interventional study covering a period of five months. We recruited 47 patients, ranging in age from 18 to 77 years and with a mean HbA1c of 8.2% (6.6% - 13.2%), through random sampling among diabetic individuals, using two structured and well-established questionnaires. Glycemic and lipid measurements (HbA1c-HDL-LDL-TR...) were taken by rapid result devices; on the other hand, physical parameters were measured by an impedance meter. We evaluated the patient's sedentary lifestyle by measuring the number of steps they took each day with a pedometer over the course of a week. The exclusion of subjects with associated and severe diseases was essential, as this would prevent them from participating in the physical activity program. These individuals followed a moderate-intensity PA regimen according to the criteria developed by the WHO and a well-monitored diet. We measured all parameters at T0, T1 (1 month after T0), and T2 (3 months after T0).**Results**: Results showed that 72% were female, and only 9% of the study population were considered non-sedentary. Analysis of variance (ANOVA1) showed a highly significant difference after 3 months of physical activity on Hba1c (p=0.000), cholesterol, HDL, and LDL (p=0.006), fasting blood glucose (p=0.000), and fat levels (p=0.003). The Hba1c level improved by 1.36%, and the mean went from T0.
The score increased from 8.28 to 6.92 three months after the diet. However, we found no significant difference in weight and muscle mass (p > 0.05). The triglyceride level showed a decrease, although it was not statistically significant (p = 0.14).
The odds ratio for having a fat rate higher than 30% in women is 0.22 times higher than in men. A sedentary lifestyle was found to be a risk factor for Hdl, Hba1c, TR, and Ldl. The odds ratio for having an Hdl rate > 0.4 g/l was 1.87 times higher than for someone who wasn't active. The odds ratio for having an Hba1c > 7% was 1.162 times higher than for someone who wasn't active. The odds ratio for having a TR > 1.5 g/l was 1.95 times higher than for someone who wasn't active. Sedentary people face a risk of having a HbA1c level higher than 7, which multiplies by 1.162. However, the age factor confirmed a risk for cholesterol, according to Cramer's value (0.505 < 0.6), so we can conclude that the relationship between age and cholesterol is medium (50%).The results also show a high sedentary rate, likely due to the predominance of women who have historically been less active in daily life. It was found that the modified exercise program helped improve the changes in HbA1c, HDL, LDL, and the fat rate. This is because the exercise increases lipid metabolism, makes it easier for muscles to transport and use glucose during exercise, and lowers insulin resistance.
Conclusions: Physical activity has confirmed its effectiveness in restoring several glycemic and lipidic parameters for type 2 diabetics, making it a better means of preventing complications related to this type of diabetes, in addition to drug treatments and a balanced diet.

1- Introduction:

Type 2 diabetes is a prevalent and constantly increasing metabolic disease worldwide, representing a real public health challenge. According to the World Health Organization (WHO), the number of people with diabetes has almost quadrupled since 1980, reaching approximately 422 million cases in 2014 (WHO, 2016). Changes in lifestyles, including increased sedentary lifestyles and changes in eating habits, largely explain this phenomenon. The disease is characterized by chronic hyperglycemia due to insulin resistance and/or impaired insulin secretion, leading to microvascular (retinopathy, nephropathy, neuropathy) and macrovascular (cardiovascular diseases) complications.

In the Oriental region of Morocco, where socioeconomic disparities and limited access to health care greatly influence the prevalence and management of chronic diseases, type 2 diabetes is a major community health problem (Bensaid et al., 2020). This region is characterized by high rates of sedentary lifestyle, a significant prevalence of obesity, and specific environmental factors, such as rapid urbanization and changes in traditional eating habits. These factors contribute to the rising rate of diabetes and the difficulty of controlling it.

Several studies have established the link between physical activity and the improvement of metabolic parameters in diabetic patients. Regular physical activity helps to reduce fasting blood glucose, improve glucose tolerance, and increase insulin sensitivity. It also plays a key role in reducing body weight and preventing cardiovascular complications, which are the leading cause of mortality in diabetic patients (Colberg et al., 2016). Furthermore, integrating structured exercise programs into primary health care is crucial to enhance patient adherence and ensure the sustainability of beneficial effects.In the Oriental context, however, physical activity-based interventions face several challenges. These include a lack of sports infrastructure, low awareness of the importance of exercise, and cultural and social beliefs that may discourage regular physical activity, particularly among women. Despite these challenges, some local initiatives have emerged to promote a more active lifestyle.

This article aims to explore the impact of physical activity on the management of type 2 diabetes in the Oriental region of Morocco. We will assess the effects of different exercise programs on metabolic parameters of diabetic patients, including blood glucose, HbA1c, body weight, and lipid profiles, as well as examine the barriers and facilitators to the adoption of these programs in this specific geographical context. The final objective is to propose recommendations for the development of adapted and sustainable intervention strategies, thus contributing to the improvement of the quality of life of diabetic patients in this region.

2- Materials and methods

2-1 Type of study:

This is a prospective interventional study that covers a period of 3 months. The study focuses on a group of 47 individuals with type 2 diabetes. The purpose of this study is to demonstrate the effectiveness of PA in treating type 2 diabetes.

2-2 Place of study:

The study was carried out at a physiotherapy practice located in the heart of the city of Oujda; the latter is equipped with sufficient equipment and devices to integrate patients to practice their exercises at this center easily.

2-3 Target population:

This study targeted a population of type 2 diabetic patients who agreed to participate in the PA program after receiving a phone call from former diabetic patients or colleagues. We randomly but inadvertently

conducted the sampling. We considered the first 50 arrivals that met the inclusion and exclusion criteria.
- Inclusion criteria: known type 2 diabetic patients aged 18 and over
The exclusion criteria includes cases with associated diseases such as advanced age and osteoporosis, which can potentially harm the health of this category during physical exercise.

2-4 Intervention

Type 2 diabetic patients agreed to participate in the PA program after a telephone call to former diabetic patients or those referred by work colleagues. Sampling was random but accidental. We considered the first 50 patients who met the inclusion and exclusion criteria.

- The inclusion criteria are for known type 2 diabetic patients aged 18 and over.

- Exclusion criteria: cases with associated illnesses (advanced age, osteoporosis, etc.) that could adversely affect the health of this category during exercise. This prospective interventional study covers three months on a sample of 47 patients and aims to prove PA's effectiveness on T2D. All participants gave their informed consent before participating in the study.

The PA program combined endurance and resistance work three times a week. The World Health Organization (WHO) mandates either 150 to 300 minutes per week for moderate endurance and intensity or 150 minutes of sustained intensity twice a week.

The population targeted by this study comprised type 2 diabetic patients aged 21–77 (the average age of patients was 49 ± 13 years) who agreed to participate in the PA program after a telephone call. Men accounted for 28% of cases, while women comprised 72% of the sample studied. The study took place at a physiotherapy practice in Oujda, Northeast of Morocco, which has enough equipment and devices to enable patients to easily practice their exercises at this center.

Our activity was as follows:

- 20 minutes of elliptical training;

- 15 min treadmill;

- 10 minutes of static and dynamic strengthening of the quadriceps and hamstring muscles against a resistance that represents 75% of the maximum resistance (RM) performed by the patient;

- Spend 10 minutes strengthening your biceps and triceps using dumbbells.

- Perform 10 minutes of static work on the lower, upper, and middle abs;

- Stretch all muscle chains for 7 minutes.

The total minutes per week was 186 min, which corresponds to the requirements of the global recommendations targeted by the WHO.

2-5 Quiz and other lifestyle factors

The other data were collected by surveys concerning the patient's level of education, living environment (rural or urban), socio-economic profile, marital status, and sedentary lifestyle. The patient used a pedometer for a week to measure the number of steps they took each day, evaluating their sedentary lifestyle. We will use this data for risk analysis.

- **Measures**

We measured all parameters at T0, T1 (1 month after T0), and T2 (3 months after T0).

- **Anthropometric measurements**

The weight is measured by a professional impedance meter, which allows for the calculation of the body mass index (BMI), which in turn allows for determining the weight status, which is assessed from the values of this index, which is calculated by dividing the weight (kg) by height (m) squared (kg/m2) and classified according to the criteria of the WHO. Weight status can therefore be: lean (BMI < 18.5), normal weight (BMI between 18.5 and 24.9), overweight (BMI between 25 and 29.9), or obese (BMI between 30 and 40). It also gauges the fat rate, with a value considered normal if it falls below 30%.

- **Lipid profile**

A "Mission Cholesterol Meter" device measured the lipid profile. We took the blood sample with a slight prick at the fingertip and used a pipette corresponding to the device's requirements for absorption. The quantity of blood is then affixed to a strip and adheres by capillarity, and the values of Cholesterol, LDL, HDL, and TR are displayed on the device.

- **Hba1c**

A "Biohermes" device measured glycated hemoglobin with a boronate affinity chromatography kit, using two reagents, A (before applying blood) and B (after applying the blood). After a few minutes, the device displays the result.

The normal values of these glycemic and lipid balances can be taken as follows: (B. Draznin,2010)

HbA1c	Total Cholestérol	LDL	HDL	Triglyceride
< 7 %	< 2g/l	< 1, 6 g/l	>0.04g/l	< 2g/l

- **Statistical analyses**

We used SPSS Statistics 17.0 software to create all graphs and results. We expressed the data as mean and standard deviation. We used the KHI2 test to rank the means using letters indicating significant differences. We use ANOVA to analyze the variance of the results between T0, T1, and T2. The tests used to compare the qualitative variables are the chi-square test and multiple correspondence analysis. *P ≤ 0.05 was treated as statistically significant.*

2-6 Ethical considerations:

We respected the ethical rules and principles aimed at protecting all persons involved in this study when carrying out this research work. These principles consist of protecting the participants while ensuring their confidentiality and respect for anonymity.

Participation is completely voluntary; all persons recruited are free to accept or refuse to participate in the study at any time.Each participant received an informed consent form that they approved and signed before carrying out the interview. This document includes the rights of the participants, such as the anonymity of the data, the right to request clarification, or the right to refuse to answer questions. We process data based on the codes assigned to each questionnaire, limiting access to only student researchers and research directors. We destroyed the personal data at the end of its use.

3- Results:

3.1 Epidemiological profile :

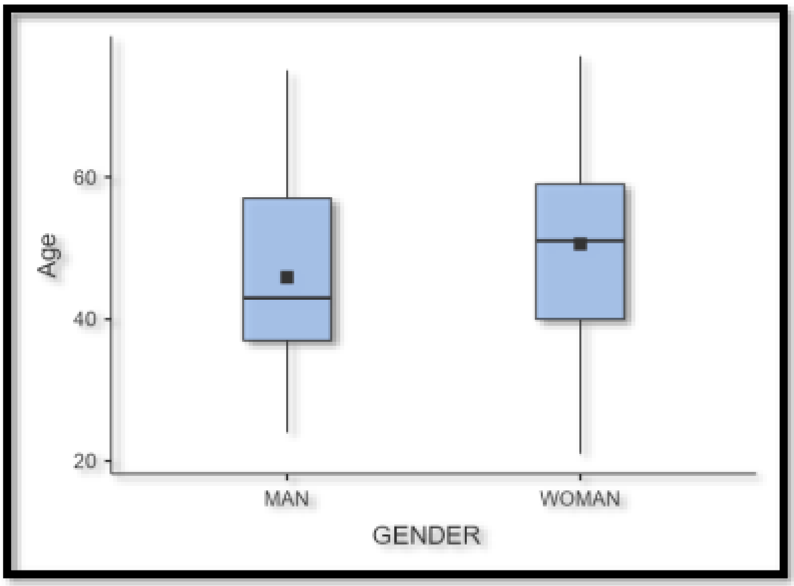


Figure 1 : Distribution of the population by age and gender

We recruited 47 patients : n = 47, the mean age of the patients was 49 ± 13 years, with extremes of 21 and 77 years. Almost 49% of the patients were over 50 years old. Men represented 28% of the cases, while women constituted 72% of the sample studied.

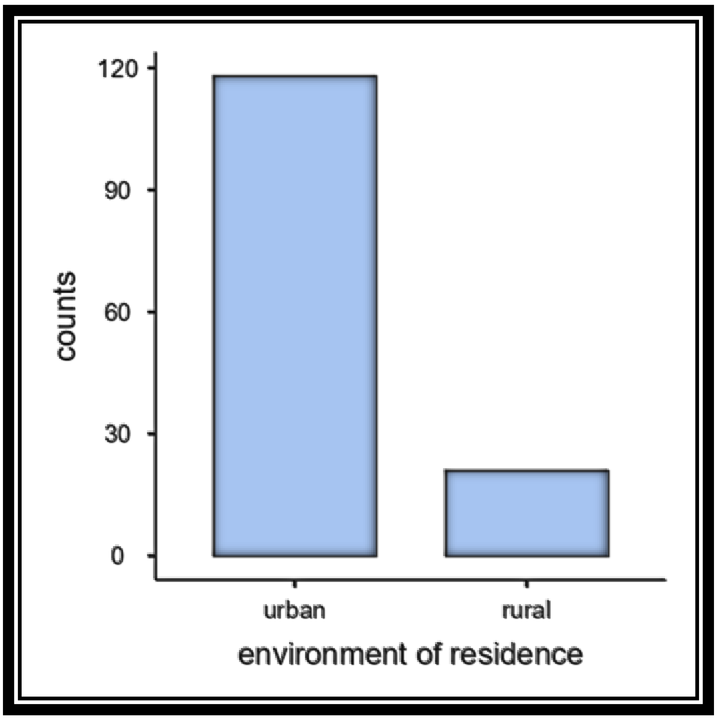


Figure 2: Distribution of the population according to living environment: The majority of the population studied (85.11%) belonged to the urban environment.

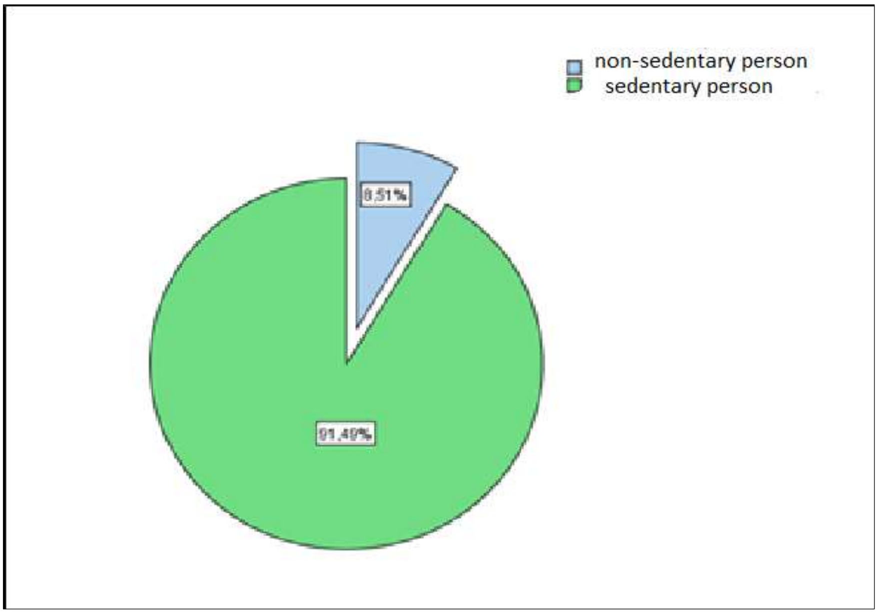


Figure 3: Distribution of the population studied according to sedentary lifestyle per week.
According to the WHO, people with a daily step count of less than 10,000 are considered sedentary. In our study, only 9% of the study population was not sedentary.

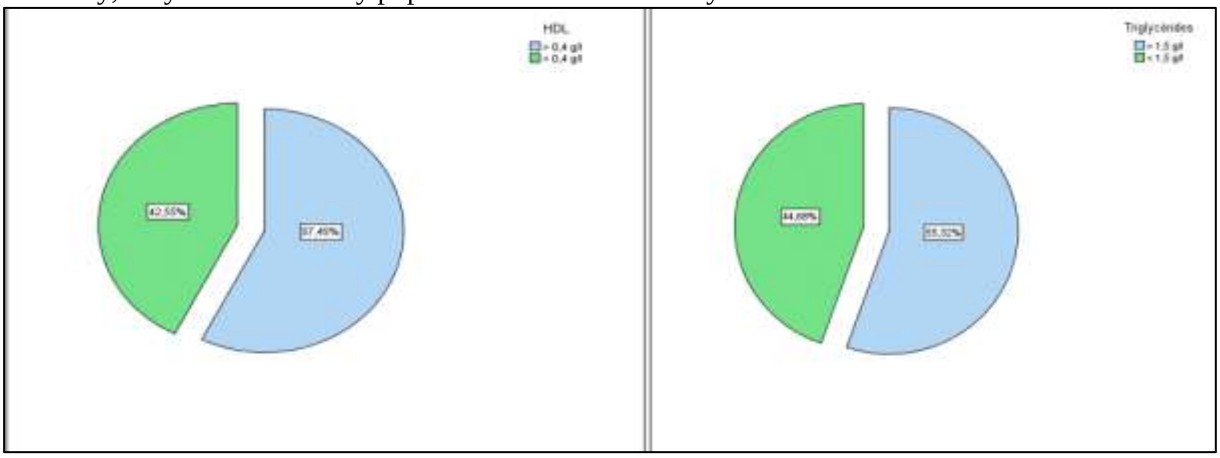
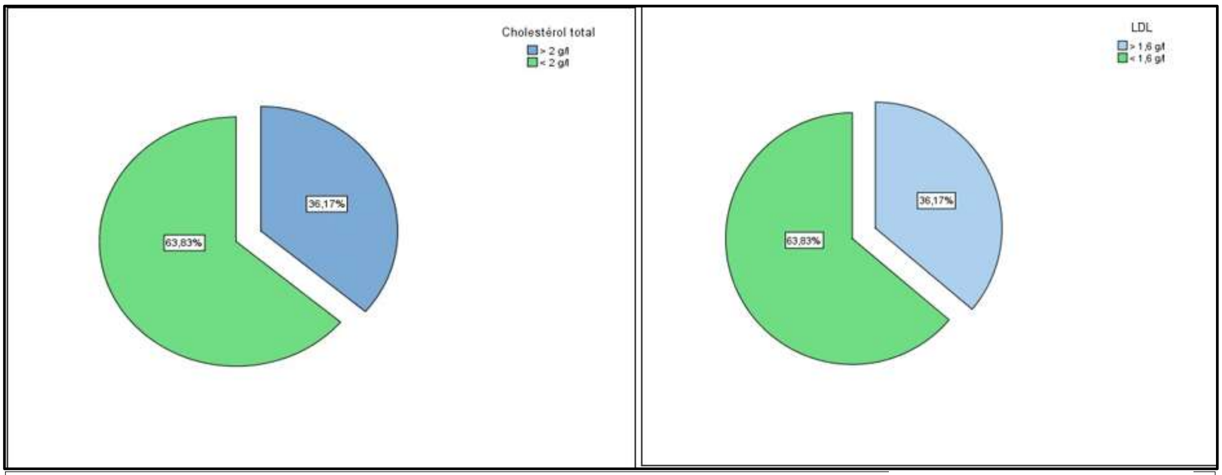


Figure 4: Distribution of patients according to HDL and TRYGLYCERIDES levels

Figure 5: Distribution of patients according to cholesterol and LDL levels

In our study, 63.83% of the sample had a total cholesterol level of less than 2 g/L, with the same percentage having an LDL level of less than 1.6 g/L. However, 57.45% of the population studied had an HDL level of more than 0.4 g/L, and 55.32% of the population had a triglyceride level of more than 1.5 g/L.



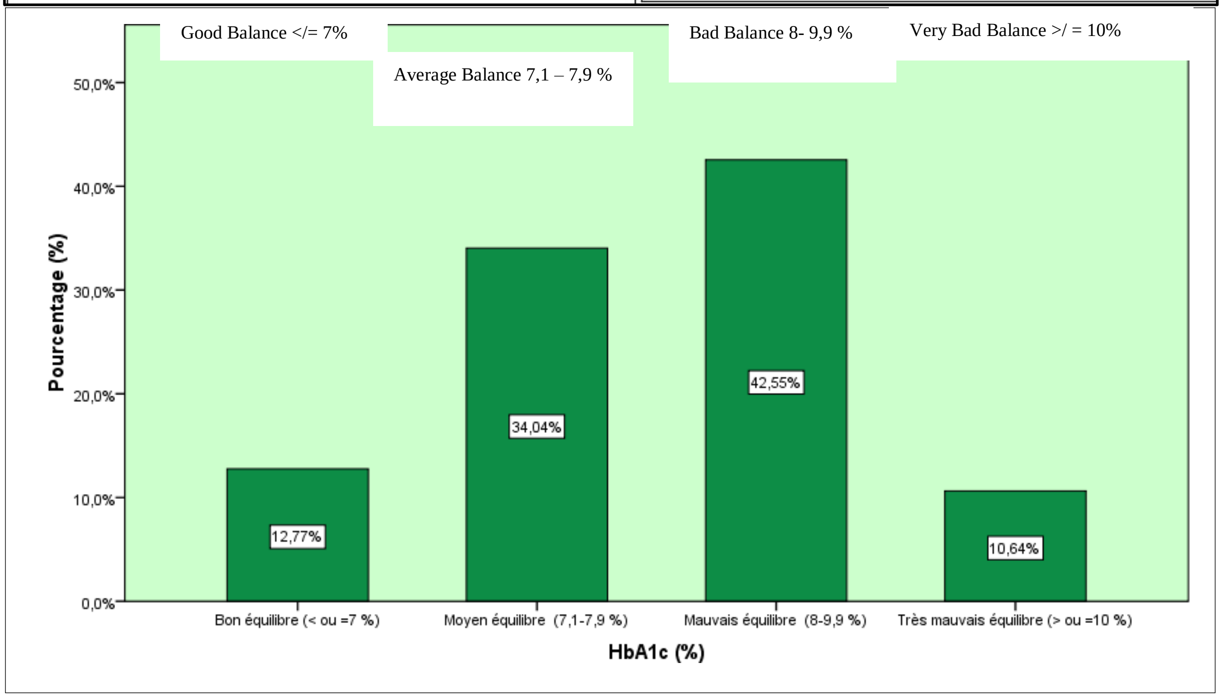


Figure 6: Initial glycemic balance in the study population

Table 1: Descriptive statistics of the HbA1c variable of the sample.

	N	Minimum	Maximum	Average	Standard deviation	Variance
Hba1c Valid N (listwise)	**47**	**6,6**	**13,2**	**8,283**	**1,2429**	**1,545**

HbA1c measurement reflects glycemic control over the past three months and is a reliable means of monitoring diabetics.

Only 12.7% of the people studied had strict control, meaning their HbA1c was less than 7%. Another 34.4% had average control, meaning their HbA1c was less than 7.9%, and 53.19% of the patients had

HbA1c greater than 8%.Initially, HbA1c was on average 8.2% ± 1.24%, with extremes of 6.6% and 13.2% (Table 1).

3.2 Evaluation of clinical parameters according to the duration of physical activity :

The following table presents the results of the analysis of variance of the variables between T0, T1 and T2. The results show a significant difference at p≤0.05 of the variables HbA1c and cholesterol (figure 7) HDL, LDL (figure 8), fat rate, between T0, T1 and T2 (figure 9). However, no significant difference in the variables weight (figure 9), triglycerides (table 2) and muscle mass is not affirmed between T0, T1 and T2 at p≤0.05 (Table 2, figure 9).

Table 2: Analysis of variance (ANOVA 1) of the variables studied between T0, T1 and T2.

		Sum of Squares	df	Mean Square	F	Sig.
weight	Between Groups	793,184	2	396,592	2,308	,103
	Within Groups	23366,176	136	171,810		
	Total	24159,359	138			
HbA1c	Between Groups	42,663	2	21,331	23,160	**,000**
	Within Groups	125,263	136	,921		
	Total	167,925	138			
Cholestérol	Between Groups	5,149	2	2,575	12,980	**,000**
	Within Groups	26,976	136	,198		
	Total	32,125	138			
HDL	Between Groups	2,889	2	1,445	18,814	**,000**
	Within Groups	10,443	136	,077		
	Total	13,333	138			
LDL	Between Groups	2,045	2	1,023	5,240	**,006**
	Within Groups	26,542	136	,195		
	Total	28,587	138			
Triglyceride	Between Groups	3,088	2	1,544	1,983	,142
	Within Groups	105,867	136	,778		
	Total	108,954	138			
Fat	Between Groups	998,903	2	499,451	6,146	**,003**
	Within Groups	11052,275	136	81,267		
	Total	12051,178	138			
Muscle mass	Between Groups	112,653	2	56,327	1,854	,161
	Within Groups	4131,224	136	30,377		
	Total	4243,878	138			

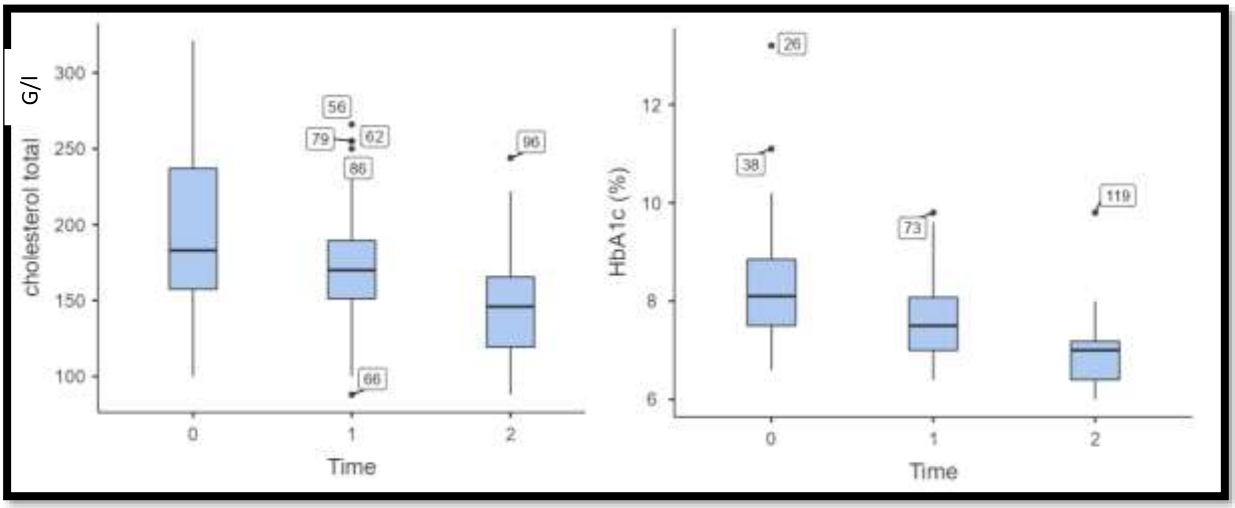


Figure 7 : Box plots representing the mean of HbA1c (%) and total Cholesterol (g/l) variables, between T0, T1 and T2. T1: 1 month after T0, T2: 3 months after T0. The difference between the letters indicates significant differences at p ≤ 0.05 based on the SNK test

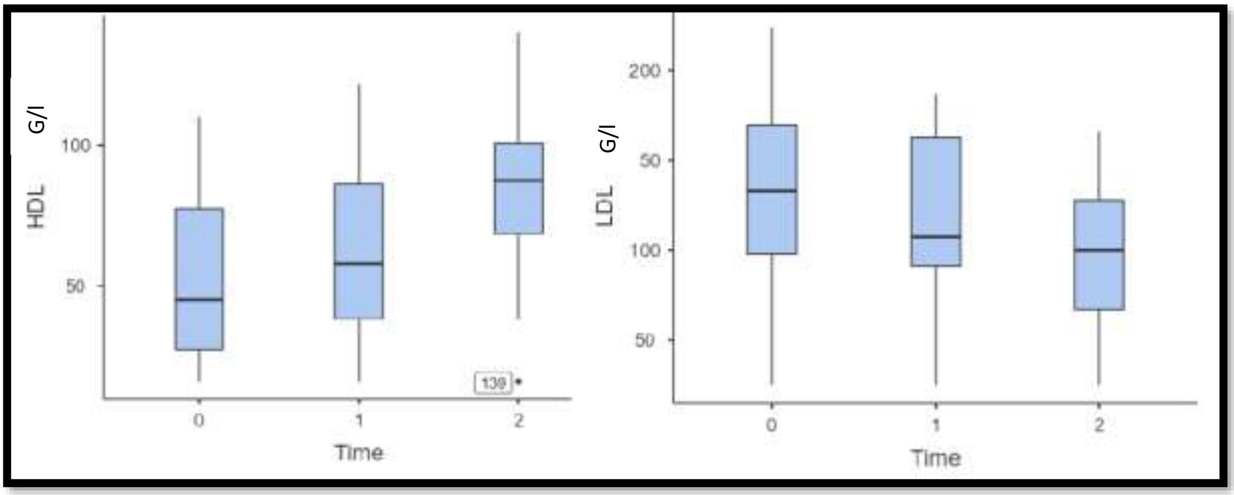


Figure 8 : Box plots representing the mean of HDL and LDL variables, between T0, T1 and T2. T1: 1 month after T0, T2: 3 months after T0. The difference between the letters indicates significant differences at p ≤ 0.05 based on the SNK test

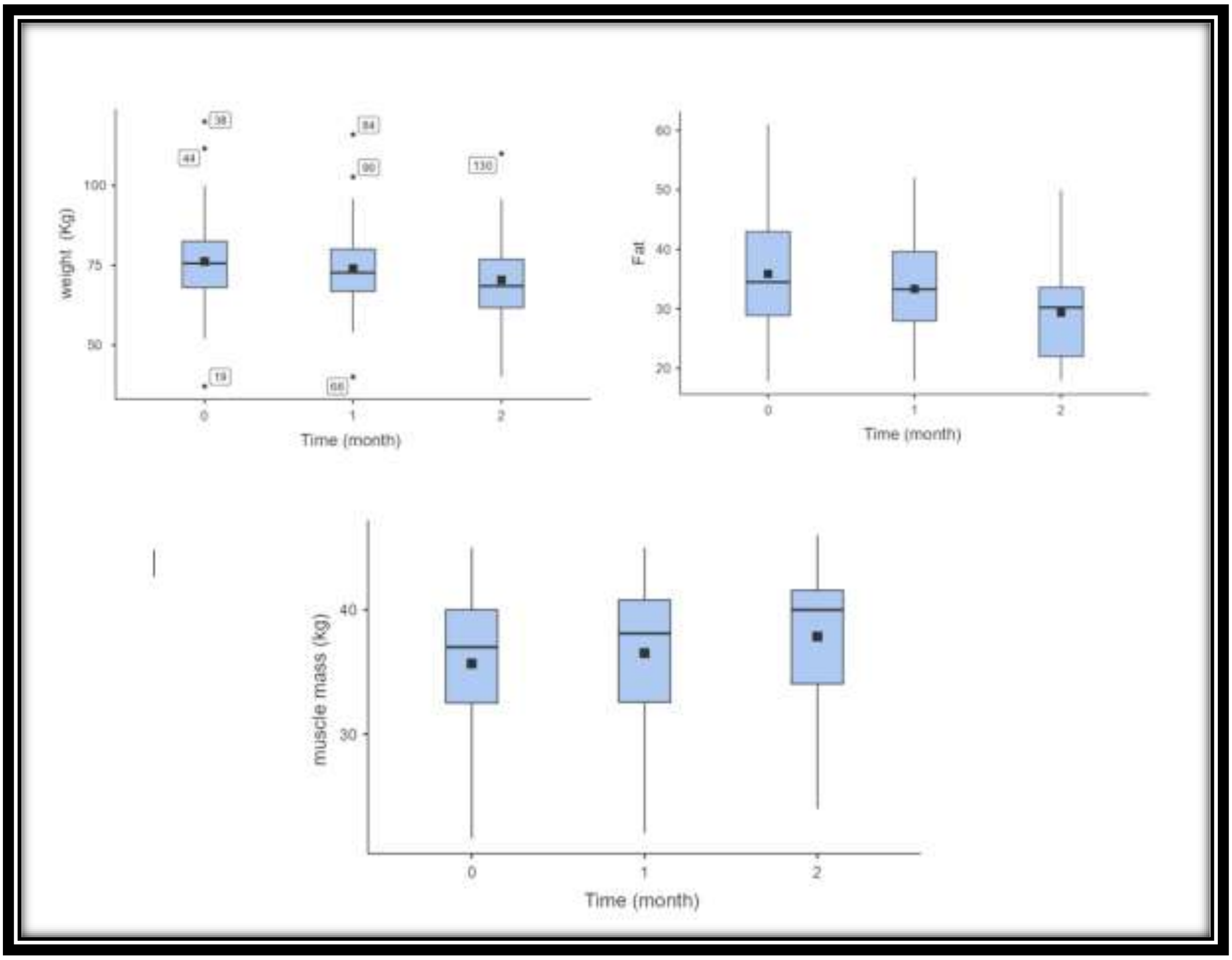


Figure 9 : Box plots representing the mean of weight, fat and muscle mass variables, between T0, T1 and T2. T1 : 1 month after T0, T2 : 3 months after T0. The difference between the letters indicates significant differences at p ≤ 0.05 based on the SNK test

3.3 Analysis of independence and risk between variables :

- **Gender factor :**

Gender*fat rate

In the risk table, we observe that the confidence interval does not include 1, so we can conclude that there is a significant association between the gender variable and the fat rate variable: Women multiply the risk ratio of having a fat rate greater than 30% by 0.222 compared to men. The chi-square test confirmed a significant relationship between the two variables, gender and fat rate, at a p-value of less than 0.05. This suggests that the gender variable influences the fat rate measured in the studied population. According to the value of Cramer's V (0.325 < 0.6), we can conclude that the relationship between gender and fat rate is weak (≈30%).(figure 10)

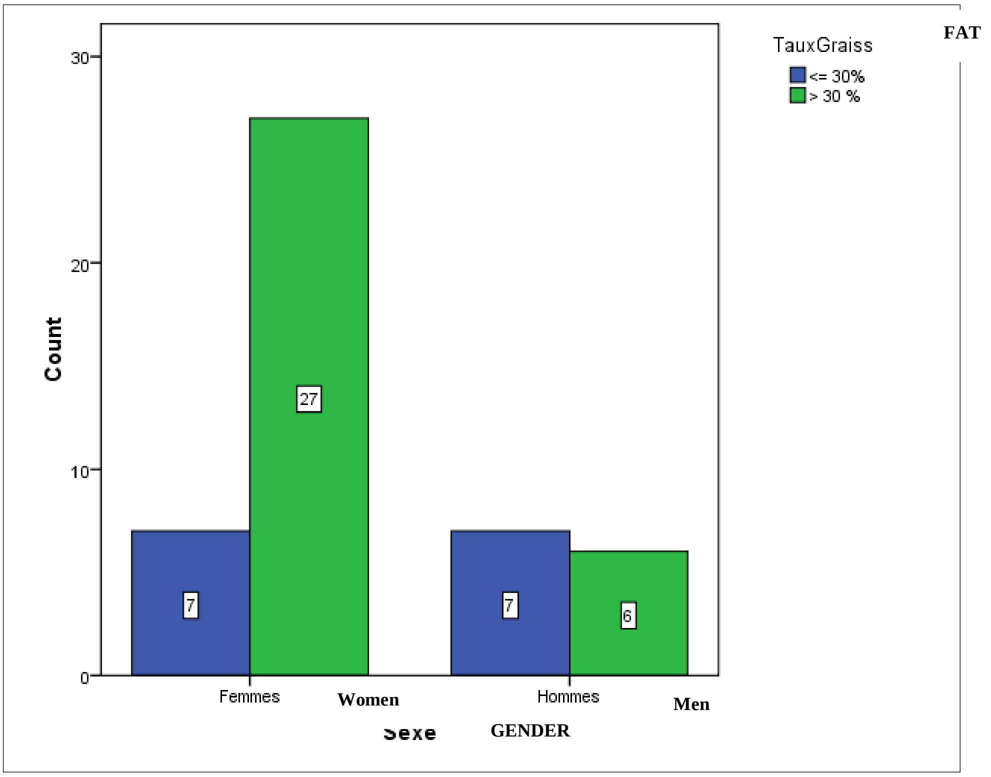


Figure 10 : Risk level between gender and fat rate in men and women of T2D

- **Sedentary lifestyle factor :**

Sedentary lifestyle *LDL

In the risk table, we observe that the confidence interval does not include 1, so we can conclude that there is a significant association between the sedentary lifestyle variable and the LDL variable : Sedentary people multiply the risk ratio of having an LDL level higher than 1.6 g/L by 3.308 compared to non-sedentary people.

The chi-square test confirmed a significance between the two variables, sedentary lifestyle and LDL, at $p \leq 0.05$, so we can conclude that these two variables affirm a relationship between them, that is to say that the sedentary lifestyle variable exerts an influence on the LDL level measured in the population studied. According to the value of Cramer's V (0.405 < 0.6), we can conclude that the relationship between sedentary lifestyle and LDL is average (≈40%).(figure 11).

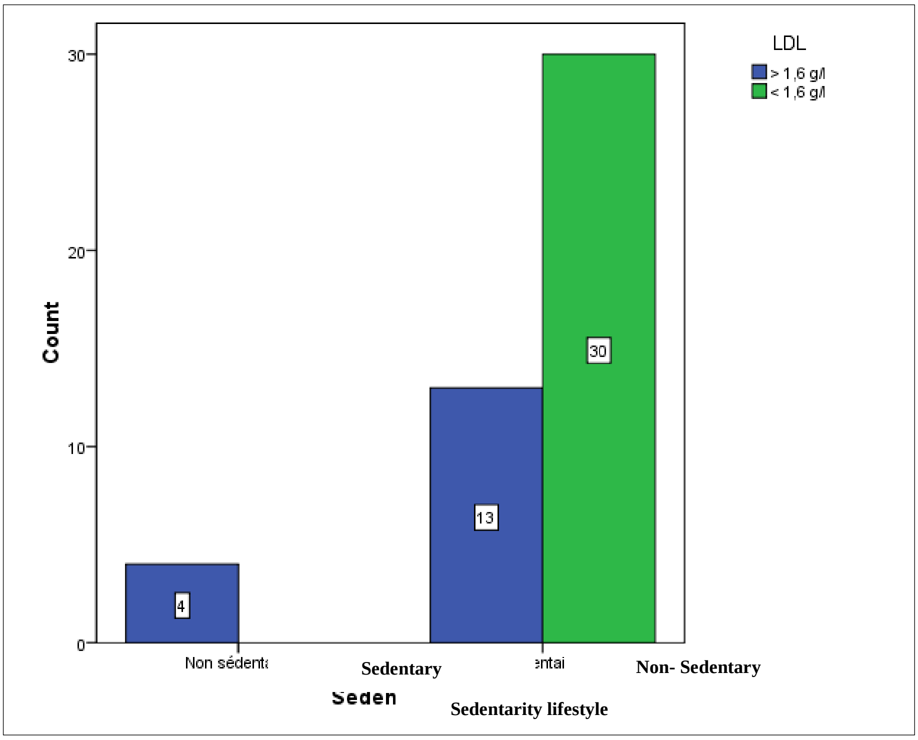


Figure 11 : Risk level between sedentary lifestyle and LDL in men and women with T2D

Sedentary lifestyle * HDL

In the risk table, we observe that the confidence interval does not include 1, so we can conclude that there is a significant association between the sedentary lifestyle variable and the HDL variable : Sedentary people multiply the risk ratio of having an HDL level lower than 0.4 g/L by 1.870 compared to non-sedentary people. However, the chi-square test showed a non-significant difference at $p \leq 0.05$, so we can conclude that these two variables are independent.(figure 12).

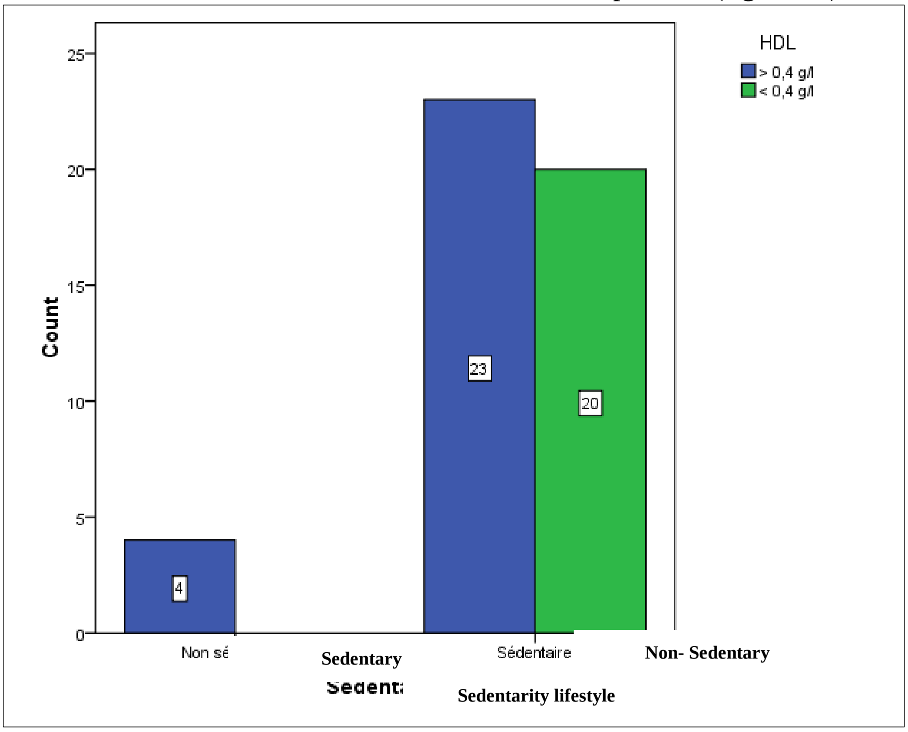


Figure 12 : Risk level between sedentary lifestyle and HDL in men and women with T2D

Sedentary lifestyle * Triglycerides :

In the risk table, we observe that the confidence interval does not include 1, so we can conclude that there is a significant association between the sedentary lifestyle variable and the triglyceride variable:

Sedentary people multiply the risk ratio of having a triglyceride level higher than 1.5 g/L by 1.955 compared to non-sedentary people. However, the chi-square test showed a non-significant difference at p ≤ 0.05, so we can conclude that these two variables are independent.(figure 13).

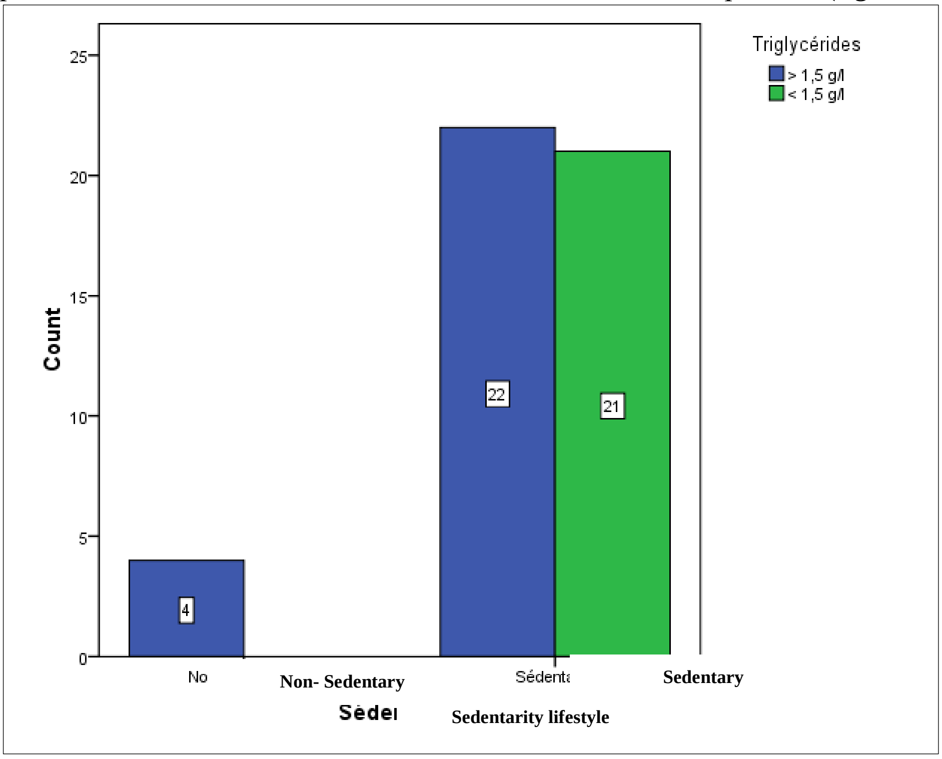


Figure 13 : Risk level between sedentary lifestyle and TR in men and women with T2D

Sedentary lifestyle * HbA1c

In the risk table, we observe that the confidence interval does not include 1, so we can conclude that there is a significant association between the sedentary lifestyle variable and the triglyceride variable : Sedentary people multiply the risk ratio of having an HbA1c level higher than 7% by 1.162 compared to non-sedentary people. However, the Chi-square test showed a non-significant difference at p ≤ 0.05, so we can conclude that these two variables are independent. (figure 14).

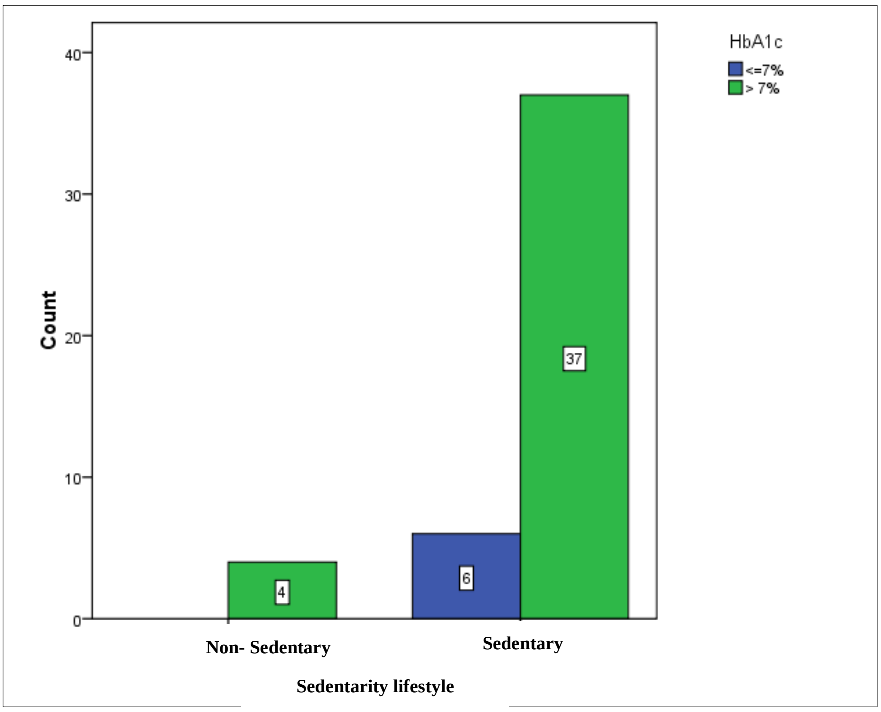


Figure 14 : Risk level between sedentary lifestyle and Hba1c in men and women with T2D

- **Environment factor**

Environment*muscle mass :

In the risk table, we observe that the confidence interval includes 1, so we can conclude that there is no association between the environment variable and muscle mass.(figure 15)

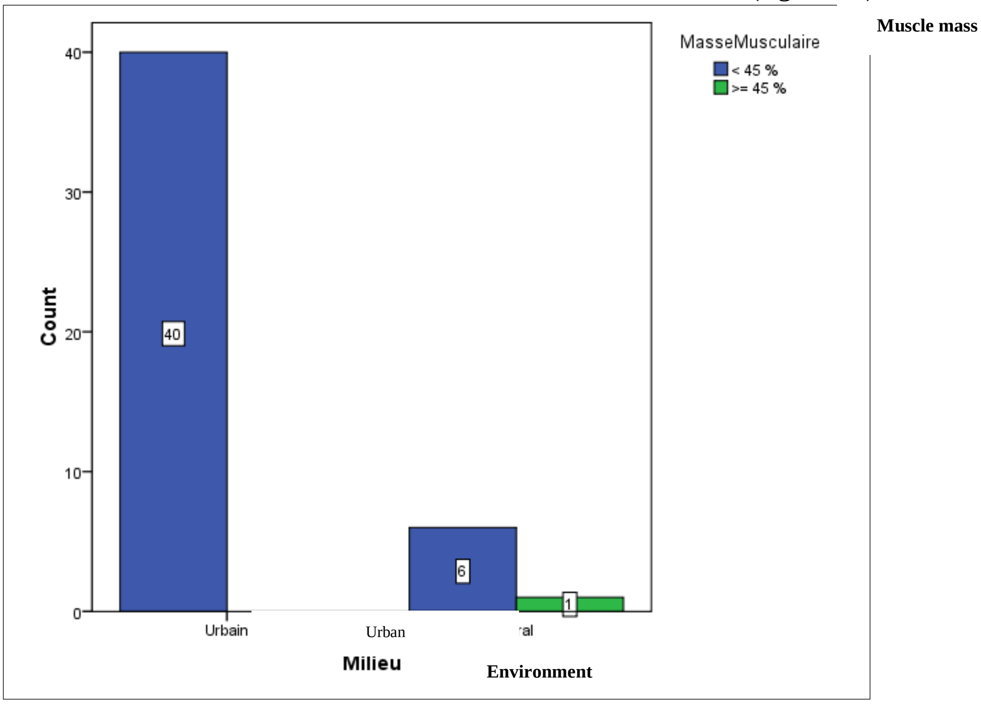


Figure 15 : Risk level between environment and muscle mass in men and women of T2D

The chi-square test demonstrated a significant relationship between the two variables, environment and muscle mass, with a p-value of less than 0.05. This suggests that the environment variable influences the measured muscle mass within the studied population. According to the value of Cramers' V (0.352 < 0.6), we can conclude that the relationship between sex and fat rate is weak (≈30%).

- **Age factor :**

Age * Total cholesterol :

The chi-square test confirmed a significance between the two variables, age and total cholesterol, at $p \leq 0.05$, so we can conclude that these two variables affirm a relationship between them; that is, the age variable exerts an influence on the total cholesterol measured at the level of the population studied. According to the value of Cramer's V (0.505 < 0.6), we can conclude that the relationship between age and cholesterol is average (≈50%).

According to the results of the risk analysis and the independence analysis, it can be concluded that the sex factor presents a risk on the fat rate with a significant dependence between the two, while the sedentary factor presents a risk on the HDL, LDL, triglyceride, and HbA1c rates with independence. However, the age factor presents a risk to the cholesterol rate, and the environmental factor presents a risk to muscle mass.

Multiple component analysis:

The correlation matrix (Table 3) reveals that certain elements exhibit sufficient correlation (r > 0.4), while others show no significant correlation, leading us to conclude that they measure the same construct. Table 8 presents the discrimination measures of the indicators on the axes; we observe that the variables of age, number of children, socioeconomic level, and level of education best discriminate the patients on the first axis, while the other variables do not have significant discriminatory power. . Therefore, we will interpret the data using the most relevant variables from the analysis. The eigenvalues obtained for the two axes, F1 and F2, exceed 50%. They are of the order of 64.79%. These two axes provide very satisfactory information.

Table 3 : Discrimination measure of variables between the two dimensions 1 and 2

	Dimension		
	1	2	Mean
Gender	,186	,034	,110
Instruction	,663	,047	,355
Environment	,119	,191	,155
Age	,601	,472	,536
Socio-economic level	,424	,115	,269
Marital status	,490	,123	,306
Number of kids	,658	,363	,511
IMC	,179	,251	,215
HbA1c	,035	,010	,023
Sédentarity	,050	,178	,114
Cholestérol	,066	,234	,150
LDL	,009	,255	,132
HDL	,032	,308	,170
Triglycerides	,008	,103	,056
Fat	,054	,062	,058
Muscle mass	,000	,208	,104
Active Total	3,574	2,955	3,264

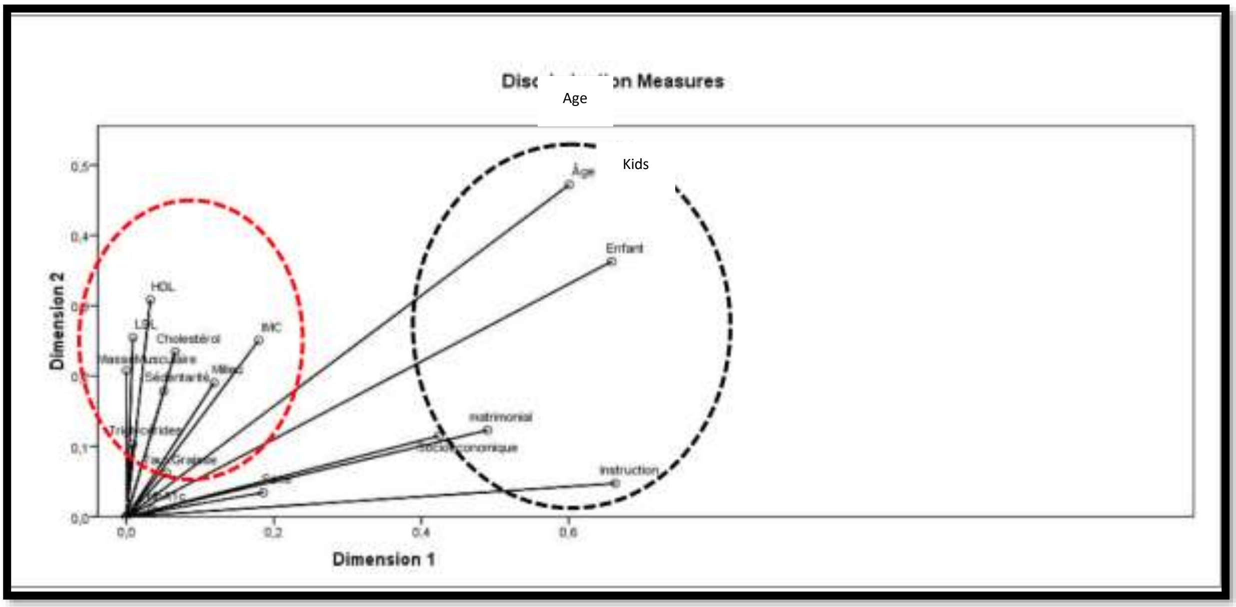


Figure 16 : MCA discrimination measures between variables

So, the two dimensions that were kept allow for a flat graphic representation of 65.29% of the total inertia rate that can be understood in terms of the distances between observations. This rate is used to show or rate the quality of the representation of the modalities or individuals on the F1xF2 plane. For the interpretation of the axes, focus on the most structuring variables—that is, those whose correlation ratio is closest to 1, as expressed in the figure above.

4- Discussion :

This study was done in the city of Oujda in eastern Morocco. Its goal was to show that a moderate-intensity PA program that included both endurance and strength training could help treat type 2 diabetes in 47 women and men who were already known to have it. We measured the program effect by considering certain physical and blood biological parameters of the patients before the program (T0) and after the program (T1, one month after T0; T2, three months after T0). The average age of the individuals ranged from 49 to 13 years, with extremes of 21 and 77 years, indicating that T2DM can affect both young and old subjects. Moreover, almost 49% were over 50 years old. In comparIn contrast to a case-control study that was done over three years in the endocrinology department of the Hassan II University Hospital in Fez, Lahmamsi et al. (2021) found two groups of patients: group A was put on an AP and hypoglycemic diet, and group B was not. The average age of the patients in group A was 45.57 years. ear female predominance.

In our study, the majority of patients (85.11%) resided in urban areas, and 74.47% had formal education, which aided in their travel and punctuality when adhering to the rehabilitation center's diet. Despite 40.43% of patients having a low socio-economic level, their participation in the services and assessments was voluntary.

Almost 91% of our diabetics were sedentary, which may be linked to the predominance of women, 72.34%, among others. Among them, 68% were married, 51% had 1 to 3 children, and 19% had more than 4 children. Women are known for their low activity levels during the day, according to Esteban (2016), who estimates that women are less active than men, regardless of age.

The calculation of the body mass index (BMI) in our sample showed that 55% of patients had a normal weight, 23% were overweight, and 2% were obese. While more than half of the population studied had a normal weight, 70% had a fat rate greater than 30, indicating that a normal weight in relation to height may not necessarily translate into an abnormal fat rate in the abdomen or buttocks. Therefore, by linking it with the rate of muscular performance, which was only 2.13%, we deduce that it is the sedentary lifestyle that has modified the body schema and comes into play in muscular weakness. According to an English study (Jimmy Mohammed 2020), just two weeks of physical inactivity can significantly increase the risk of chronic diseases like diabetes, highlighting the importance of daily movement. Their study shows that after just two weeks of inactivity, a risk is present in healthy people. Indeed, this period of inactivity is sufficient to reduce muscle mass and produce visible metabolic changes in these people. To reach this conclusion, the researchers called upon 28 healthy, physically active people (with an average of 10,000 steps per day) aged 25 and who had a normal body mass index (BMI). All participants wore a special armband to measure their physical activity. They also underwent a comprehensive health check-up, measuring their muscle and fat mass rates, their cells' mitochondrial function (ability to regulate energy and recover from exercise), and their physical condition. We conducted these assessments at the beginning of the study.

The participants underwent a daily step reduction protocol for 14 days. Thus, the participants reduced their daily average from 10,000 steps to just 1,500 steps.

Every day, they experienced an 80% decrease in their physical activity. They had to keep a dietary diary so as not to make any changes to their food intake throughout the study. The analyses revealed a decrease in physical activity time from 161 minutes to 36 minutes per day, resulting in an average reduction of 125 minutes. At the same time, the prevalence of sedentary behavior increased to an average of 129 minutes per day. We observed significant changes in the participants' body composition after this period of inactivity, including a loss of muscle and skeletal mass and an increase in total body fat. This body fat tended to accumulate in the "center," and abdominal fat is a major risk factor for chronic diseases. [83].

Regarding the lipid profile, 64% of our study population had cholesterol less than 2 g/l, LDL less than 1.6 g/l, and 57.45% had HDL greater than 0.4 g/l; on the other hand, 55% had a triglyceride greater than 1.5 g/l, which formally corresponds with the BMI rate. HbA1c had an average of 8.2% ± 1.24%, 34% had a moderately balanced glycated hemoglobin, 13% had a stricte balance, and 53% did not have a good balance (> 8%). The results, after 3 months of moderate physical activities, showed that the average

HBa1c rate significantly improved by 1.36 with a high significance (p = 0.000), and the average went from 8.28% at T0 to 6.92% at T2. The study conducted by Lahmamsi et al. (2021) observed a noteworthy improvement (p = 0.03) over a two-year duration. According to Claire (2019), the reduction in HbA1c in diabetics can be 0.6% (0.3-0.9) for training of the order of 3 sessions of 60 min per week, regardless of any caloric restriction and weight loss. The increase in HbA1c is comparable to the impact of new anti-diabetic treatments. This effect is obtained regardless of the type of training (resistance, endurance, or mixed), as long as it is supervised and seems all the more significant as the weekly volume is high. Other results along the same lines are summarized in Table 4 below:

The study	Authors	Type of study	Results
1	Thomas DE et al. : 2006	Meta-analysis 14 randomized studies 377 patients of average age 60 years with a follow-up of 8 weeks to one year.	Regular AP improves glycemic balance leading to a 0.62% decrease in HbA1c (95% CI [-0.91;- 0.33] p< 0.05 Effect comparable to oral drug treatments for diabetes (mean decrease of 0.3% to 0.9%). Thomas, Cochrane review 2006
2	Boulé et al. (2001)	Meta-analysis on 14 studies	AP: decrease in HbA1c: - 0.66% compared to the control group (7.65% vs. 8.31%, P<.001)
3	Snowling et al. (2006)	Meta analysis 27 studies Training > 12 weeks	↓ HbA1c 0,8% +/- 0.3% [IC 90%]
4	Sigal et al.	prospective study	Prospective study involving 377 subjects, average age 60 years) with a control group. The intervention period extended according to the studies between 8 weeks and 12 months. Compared to the control group, the practice of regular physical activity significantly improves glycemic balance with an average decrease in HbA1c according to the type of work. Aerobic work: -0.51%. Resistance work: -0.38%. Resistance work + aerobic work: - 0.46% compared to aerobic work alone And -0.59% compared to resistance work alone. So the best result was that of both resistance and aerobic work
5	Lehmamsi FZ Aitifali	Descriptive and analytical case-control study, 3-year	45.57 years. With a clear female predominance. In group a (under AP and RH): weight loss was estimated at 4.2 kg

	H.Salhi H El Ouahabi	duration of diabetics under AP and diet	± 3.6 after 6 months of follow-up, 6.4 kg ± 4.9 after one year of follow-up, 7.8 kg ± 10.6 after 2 years of follow-up and had better glycemic balance with a mean HBA1C of 7.9% vs 9.3% ($p < 0.05$). The mean triglyceride level was 1.5 ± 0.2 g/L, that of HDL was 0.46 ± 0.18 g/L with a significant improvement p = 0.03 after two years of follow-up in group a compared to controls.
6	L.Pedro G .Vaillant R.Abbas M.Habchi S.Verret	prospective study in 98 T2D patients, practicing an adapted physical activity, in the Mobile Therapeutic Education Unit/Diabetes of the Haute Côte d'Or health network. Capillary blood glucose levels were measured before and after each physical activity.	All physical activities Lead to a decrease in capillary blood glucose of 0.5 g/L on average. For the entire population, the decrease in blood glucose was significantly greater with swimming (– 0.59 g/L) than with walking (– 0.46 g/L; $p < 0.001$) or gymnastics (– 0.31 g/L; $p < 0.001$). In the subgroup of 26 patients who performed the three activities, statistical analysis using a hierarchical model showed superiority of swimming over gymnastics (OR = 1.24, $p < 0.001$) and of swimming over walking (OR = 1.07; p = 0.02) in reducing blood glucose. Regardless of the treatment, 39 episodes of hypoglycemia (threshold < 0.7 g/L) were recorded, mainly after swimming.
7	Agnès Hartemann	Meta-analysis distinguished between supervised, structured physical activity (endurance, resistance, or a combination of both) versus simple recommendations for daily physical activity. Across 47 randomized studies,	The results show that supervised and structured physical activity leads to a significant improvement in HbA1C levels of 0.51% to 0.73% compared to the other group, depending on the training program.
8	Baldi et al (2003)	Meta-analysis on 18 type 2 diabetic men, without oral treatments, 10-week period, resistance work 3 times per week	HBA1c decreased by 1.6%
9	Dela, et al. 2004	Endurance (5 times/week) on 16 men and women with oral	- 0,7 % HBA1c

		hypoglycemic agents for 3 months.	
10	Kemps et al. 2019	Systematic review on the impact of physical training (aerobic and resistance) in patients with T2DM also suffering from cardiovascular diseases.	Combined aerobic and resistance exercise programs reduced HbA1c by 0.7% and improved cardiorespiratory fitness. Reduction in cardiovascular events through improved insulin sensitivity and weight loss
11	Anna K. Jansson et al. 2022	Meta-analysis of 20 randomized controlled studies examining the impact of resistance training on HbA1c in 1,172 adults with type 2 diabetes.	Resistance training significantly reduced HbA1c (-0.39%) and improvements in muscle strength were associated with greater reduction in HbA1c. There was no significant difference between resistance and aerobic training.
12	the present study	47 male and female patients With oral hypoglycemic treatment. Moderate endurance and resistance work (3 times a week) duration 3 months	Mean HbA1c improved by 16.42%. People with HBa1c <7 increased by 53.66%. (p=0.000)

For blood sugar, the average decreased by 1.36g/l, where at t0 was 1.68g/l and t2: 1.23g/l, so the decrease in blood sugar was 0.45g/l, and the improvement was highly significant (p=0.000). Unlike a study conducted respectively at CHU Mondor, Saint-Maur CHU Dijon, Dijon CHU Saint-Étienne, Saint-Etienne, in 2014, in 98 T2D patients, practicing an adapted physical activity, in the Mobile Therapeutic Education Unit/Diabetes of the Haute Côte d'Or health network, where capillary blood sugar levels were measured before and after each physical activity. For the entire population, the decrease in blood sugar was significantly greater with swimming (–0.59 g/L) than with walking (–0.46 g/L; p < 0.001) or gymnastics (–0.31 g/L; p < 0.001).[85]. In our study, a significant improvement was also noted for the HDL rate with (p = 0.000), LDL (p = 0.006) and the fat rate (p = 0.003).

The change in weight rate was not significant (p=0.1). This could be due to the insufficient PA period. According to Claire (2019), PA does not allow weight loss at the levels typically practiced. For training levels that reduce HbA1c by 0.6%, the average weight loss is only 540 g. Several explanations are possible: Physical activity-related energy expenditure pales in comparison to the 24-hour total; resting energy expenditure and food intake exhibit clear variability across subjects.

Beyond weight variations, it is the impact on body composition that is interesting: physical activity helps maintain or even increase lean mass, particularly resistance exercises; it helps reduce fat mass, although the distinction between subcutaneous fat mass and visceral fat mass is not straightforward to demonstrate. Preserving muscle mass is important since it constitutes the primary source of glucose utilization (Clair 2019) .

Similarly, some risk factors, such as a sedentary lifestyle, dramatically increase certain biological parameters such as HDL, HbA1c, TR, and LDL. The ratio of having an HDL level > 0.4 g/l was multiplied by 1.87 compared to non-sedentary people, the ratio of having an

HbA1c > 7% was multiplied by 1.162, the ratio of having a TR > 1.5 g/l was multiplied by 1.95, and the ratio of having an LDL > 1.6 g/l was multiplied by 3.3 compared to non-sedentary people. Physical activity is important for the treatment of type 2 diabetes as well as for a balanced diet. PA is not just sport. It is also daily activity (walking, climbing stairs, swimming, cycling, gardening, walking the dog, etc.). To be effective, it must be sufficiently prolonged and regular. This is a change in behavior. Interest in physical activity allows us to “break” with the caloric obsession by guiding the patient towards a more global management of their health.

5- Conclusion

Regular and adapted PA with a balanced diet, constitutes a pillar in the management of the diabetic patient.

It can be said that physical activity is an integral part of the therapeutic management of type 2 diabetes, prescribed in an adapted and progressive manner has shown its favorable effect on physical, glycemic, and lipid balance.

Assessing the patient's degree of motivation to change their behavior and integrate physical activity into their lifestyle is a fundamental step in management and prescription. Regular reassessment of this motivation, as well as that of physical activity, its consequences and objectives is equally necessary.

Bibliographic references:

- Organisation Mondiale de la Santé (OMS). *Rapport mondial sur le diabète*. Genève : OMS, 2016.
- Bensaïd et coll. (2020). Bensaïd, A., et al. *Disparités socio-économiques et gestion des maladies chroniques dans la région de l'Oriental au Maroc*. Journal de Santé Publique Régionale, 15(2), 2020.
- Colberg et al. (2016). Colberg, SR, Sigal, RJ, Yardley, JE, et al. *Activité physique/exercice et diabète : déclaration de position de l'American Diabetes Association*. Diabetes Care, 39(11), 2065–2079, 2016.
- Dr F.Z.Lahmamssi, DrW.AitifaliPrH.Salhii, “Évaluation des effets de l’équilibre alimentaire et de l’activité physique sur le contrôle glycémique chez les diabétiques de type 2 en surpoids ou obèses,” *2021*, vol. 82, no. 5, p. 484.
- A. C. N, “Activité physique et diabète de type 2,” 2019.
- Effet de l’activité physique en milieu aquatique sur les glycémies au cours du diabète de type 2,” *Diabetes Metab.*, vol. 40, p. A32, 2014.
- Balducci S, Iacobellis G, Parisi L, “Exercise training can modify the natural history of diabetic peripheral neuropathy,” vol. 20, pp. 2016–223, 2006,doi: 10.1016/j.jdiacomp.2005.07.005.
-Boulé, NG, et al. (2001). Effets de l'exercice sur le contrôle glycémique et la masse corporelle dans le diabète de type 2 : une méta-analyse d'essais cliniques contrôlés. *Soins du diabète* .
- Sigal , NG, et al. (2001). Effets de l'exercice sur le contrôle glycémique et la masse corporelle dans le diabète de type 2 : une méta-analyse d'essais cliniques contrôlés. *Soins du diabète* .
- D. B., “Mitogenic action of insulin: friend, foe or a ‘frenemy’.,” *Diabetologia*, pp. 53:229-233., 2010.

-