

Original Article

Determinants of hyperhomocysteinemia in sports practice among individuals with type 2 diabetes in Cote d'Ivoire

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Abstract

Several studies have established a link between nutrition, physical activity, and hyperhomocysteinemia. High-intensity physical activity has been implicated as a risk factor for hyperhomocysteinemia. The objective of this study was to investigate the causes of increased homocysteine levels through physical activity in type 2 diabetics in Côte d'Ivoire. This was a descriptive cross-sectional study conducted on 181 volunteers type 2 diabetics, aged from 23 to 86 years, regularly monitored at the Abidjan Antidiabetic Center. They were submitted to the WHO Global Physical Activity Questionnaire. Homocysteine levels were measured using the enzymatic cycling method. The study revealed that the factors increasing homocysteine levels through physical activity in Ivorian type 2 diabetics were: high-intensity exercise (2.2%), particularly in males; moderate exercise equivalent to intense exercise in those over 70 years, due to the physiological decline in renal function associated with aging; the sedentary lifestyle (46.96%), particularly in those over 50 years of age; and age itself in relation to a sedentary lifestyle. Conversely, moderate exercise (50.83%) did not increase hyperhomocysteinemia, either across the 20–69 age group or according to normo- or hyperhomocysteinemic status. Moderate physical activity is protective against hyperhomocysteinemia. It can be recommended and prescribed for hyperhomocysteinemia prevention and treatment.

Keywords: homocysteine, hyperhomocysteinemia, physical activity, type 2 diabetes, Côte d'Ivoire

Introduction

Homocysteine is a non-proteinogenic, sulfur-containing amino acid, intermediate in methionine metabolism [1]. It is synthesized by all cells in the body and catabolized via two pathways: transsulfuration and remethylation [2]. This amino acid is an important indicator in assessing the risk of cardiovascular disease [3]. The plasma homocysteine level in a healthy individual is arbitrarily defined as between 5 and 15 $\mu\text{mol/L}$ [2].

Hyperhomocysteinemia is an abnormal accumulation of plasma homocysteine resulting from its bad metabolism [4]. Its causes are genetic, nutritional (vitamin B deficiencies), therapeutic, or even physiological [2].

High-intensity physical activity has been implicated as a cause of hyperhomocysteinemia [5]. The impact of physical activity on homocysteine levels varies depending on the intensity and the duration of the exercise. High-intensity physical activity increases the need for B vitamins, decreases their plasma bioavailability,



and induces hyperhomocysteinemia [5]. During intense physical activity, free radicals are produced via excessive oxygen consumption [6] and the activation of the ischemia-reperfusion process in certain tissues [7]. Prolonged intense physical activity leads to hyperhomocysteinemia through three mechanisms suggested by Venta et al. [8]: the increase in the production of free radicals, the increase in protein turnover and the turnover of methyl groups [5].

A relationship exists between nutrition, physical activity and homocysteine levels [5]. However, the relationship between hyperhomocysteinemia and physical activity in individuals with diabetes has not been studied in sub-Saharan Africa, particularly in Côte d'Ivoire. Furthermore, no research has been conducted on the determinants of hyperhomocysteinemia in exercise among individuals with type 2 diabetes in Côte d'Ivoire. The objective of this study was to investigate the determinants of hyperhomocysteinemia in physical activity among individuals with type 2 diabetes in Côte d'Ivoire. Specifically, it was to realize a survey of the physical activity frequency, to measuring homocysteine levels and then identifying the specific factors that increase homocysteine levels in the sports activities of individuals with type 2 diabetes.

Material and methods

Type of study and population

This was a descriptive and cross-sectional survey. Our study included 181 individuals with type 2 diabetes, comprising 114 women and 67 men, aged from 23 to 86 years. They were regularly monitored at the Abidjan Antidiabetic Center. This population included various Ivorian and foreign ethnic groups, with 155 nationals and 26 foreign nationals. They resided in Abidjan and other cities in Côte d'Ivoire.

Data collection

Type 2 diabetic volunteers wishing to participate in the study registered with the nurses in charge of enrollment. Sociodemographic (age, sex, body mass index, ethnic group etc.), and clinical (diabetic complications, insulin therapy status, duration of diabetes etc.) data were collected by nurses using a survey form. This data was verified using the medical database of the Diabetes Center. Informed consent was obtained using appropriate forms. The Abidjan Antidiabetic Center is a ser-

vice of the National Institute of Public Health (INSP) in Abidjan, Côte d'Ivoire. It has over 45,500 officially registered diabetics. Diabetics were selected consecutively by the voluntary sampling method [9].

Evaluation of physical activity practice

The patients with type 2 diabetes were submitted to the WHO Global Physical Activity Questionnaire (GPAQ) [10]. The questionnaire collected information on the frequency of physical activity among individuals with type 2 diabetes. The distinction between activity levels (sedentary, moderate, intense) was made using the classification proposed by the WHO [10], defined as follows: (1) Sedentary – Patients who do not engage in physical exercise but perform light work. 75% of their time was spent sitting or standing, and 25% of their time was spent standing or moving; (2) Diabetics with moderate physical activity – Patients who engage in physical exercise for 30 minutes or 1–2 hours per day, twice a week, or occasionally, but perform moderate work. 40% of their time was spent sitting or standing, and 60% of their time was spent in a specific occupational activity; (3) Diabetics with intense physical activity – Patients who engage in physical exercise for 2 hours or more per day, more than twice a week, but perform intense work. 25% of the time was spent sitting or standing and 75% of the time was devoted to a specific professional activity.

Blood sampling and determination of homocysteinemia

Venous blood samples were collected from fasting (12 hours) diabetic patients in a semi-seated position in the blood collection room of the Research and Medical Biology Laboratory at the National Institute of Public Health (INSP) in Abidjan, Côte d'Ivoire. Blood was collected in 5 ml Vacutainer-EDTA tubes, which were immediately placed in a cooler between collection and centrifugation. After centrifuging the tubes at 3000 rpm for 10 minutes, the plasma samples were aliquoted and stored at -20°C. At the time of analysis, the plasma samples were thawed at room temperature and homogenized. Homocysteine levels were measured using the Cobas c-311 automated biochemistry analyzer (Roche Diagnostics) via the enzymatic cycling method. Hyperhomocysteinemia in diabetics was defined as a level of 12 µmol/L or higher, according to the French Homocysteine Group in 2001, based on the homocysteine

classification of Faeh *et al.* [11]. Indeed, cardiovascular risk is present between 10 and 15 $\mu\text{mol/L}$ [12].

Ethical considerations

The study protocol was approved by the Technical Team of the Laboratory of Research and Medical Biology of the National Institute of Public Health (INSP) in Abidjan, Côte d'Ivoire. All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments. All participants were fully informed about the study's purpose and provided their written informed consent prior to enrollment. To ensure data confidentiality and participant privacy, all questionnaires were thoroughly anonymized during data collection and subsequent statistical analysis.

Statistical analysis

The data were recorded and then processed using Excel 2013 application. The baseline characteristics of diabetic patients (age, duration of diabetes, body mass index, and homocysteine level) were expressed as mean $\pm$ standard deviation. The significance of these quantitative variables was assessed using Fisher's test for equality of variances and Student's t-test for comparison of means. The relationship between sports practice and its frequency was assessed using Pearson's chi-squared test of independence. For these tests, significance was considered to be $p < 0.05$.

Results

Sociodemographic and clinical characteristics of the study population

The sociodemographic and clinical characteristics of the study population are presented in Figure 1 and Table 1. The mean age was 55 ± 15.55 years. The most represented age group was 50–59 years. The sex ratio was 0.6. The mean duration of diabetes was 8.5 ± 4.97 years. Diabetes was predominantly Akan (50%). 45.3% of diabetics had no formal education. 75% presented with diabetic complications, and 9% were on insulin therapy. 35.36% of diabetics had hyperhomocysteinemia, and 64.64% had normohomocysteinemia. The mean hyperhomocysteinemia was 14.87 ± 3.29 $\mu\text{mol/L}$ and the mean normohomocysteinemia was 7.71 ± 3.40 $\mu\text{mol/L}$.

Sports practice among people with type 2 diabetes

The Table 2 presents the frequencies of sports practice and the corresponding homocysteine levels, according to sex, general context, and hyper- or normo-homocysteinemic status. 50.83% of diabetics regularly practiced moderate-intensity sports. Furthermore, 2.21% of diabetics are engaged in more regular and intense sports activity. However, 46.96% of them did not practice any sports. There was no significant difference between the mean homocysteine levels corresponding to the different levels of physical activity, in the general context, in women, or according to hyper- or normo-homocysteinemic status (Table 2). However, in men, we observed a significant difference in homocysteine levels between moderate and intense sports practicing.

Sports practicing by age group is shown in Figure 2. The level of moderate sports practicing (quantified overall at 50.83% in Table 2) decreases with age: initially at 66.7% for the 20–29 age group, it is reduced to 41.2% among diabetics aged 70–86 (Figure 2). Conversely, sedentary behavior (quantified overall at 46.96% in Table 2) increases with age: it rose from 33.3% for the 20–29 age group to 58.8% among diabetics aged 70–86 (Figure 2).

Sports activity according to age group and homocysteine levels is presented in Table 3. There is no significant difference between the mean homocysteine levels corresponding to the different levels of sports activity (none, moderate, intense) across the 20–69 age group. However, in those over 70 years (70–86 age group), sports activity significantly increases homocysteine levels: on average from 6.29 ± 5.56 $\mu\text{mol/L}$ during periods of no sports activity to 12.55 ± 3.71 $\mu\text{mol/L}$ during periods of moderate exercise. In those under 50 years, a sedentary lifestyle does not significantly increase homocysteine levels. Furthermore, in ages over 50 years (50–69 years), a sedentary lifestyle significantly increases homocysteine levels.

Discussion

Sociodemographic and clinical characteristics of the diabetic population

Our type 2 diabetic population was predominantly female, with a mean age of 55 ± 15.55 years, which corresponds well to the age at which type 2 diabetes generally appears, i.e., around 40 to 50 years. In another Ivorian study, also conducted at the Abidjan Antidiabetic Center (CADA), Oga *et al.* [13] reported a mean age of

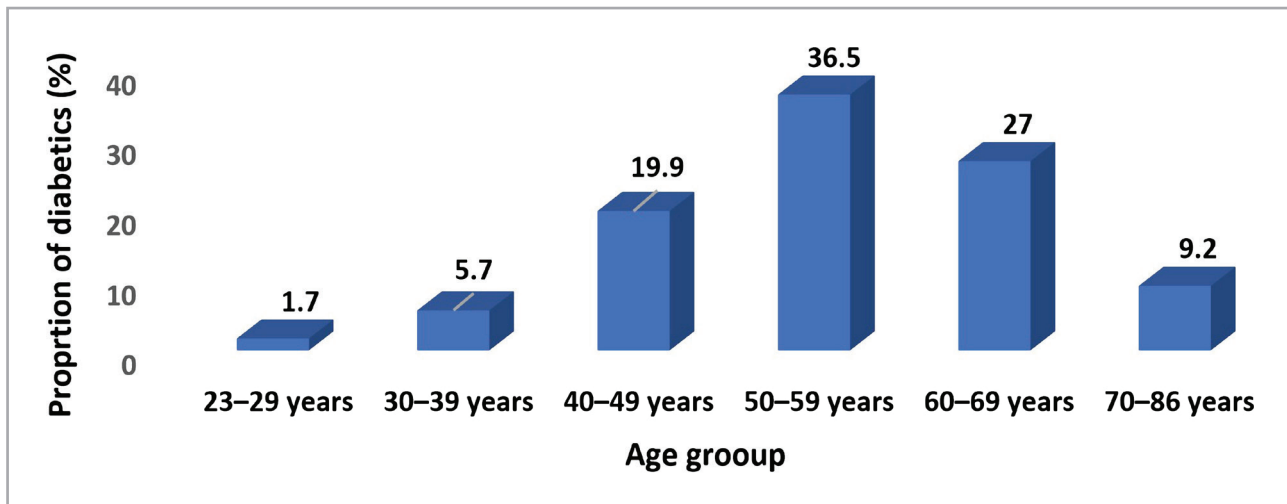


Figure 1: Distribution of type 2 diabetics by age group.

Table 1: Sociodemographic and clinical characteristics of the study population.

Diabetic population (n)	181	P
Diabetic men (n=67) (%)	37	
Diabetic women (n=114) (%)	63	
Sex ratio (M/W)	0.6	
Average age (years) (23 to 86 years)	55±15.55	<0.05
Average duration of diabetes (years) (1 to 31 years)	8.5±4.97	<0.05
Body mass index (BMI) (kg/m ²)	25.78±4.97	<0.05
Grade I obesity (%)	11	
Grade II obesity (%)	1.6	
Grade III obesity (%)	0.5	
Overweight	44.2	
Normal weight	38.4	
Underweight	4.3	
Distribution of diabetics		
Ivorians (%)	86	
African Foreigners (%)	14	
Ethnic group		
Akan (%)	50	
Gur (%)	7	
Krou (%)	10	
Southern Mandé (%)	4	
Northern Mandé (%)	15	
Other Africans (%)	14	

Table 1: Continued.

Diabetic population (n)	181	P
Education level		
Without education (%)	45.3	
Primary (%)	21.5	
Secondary (%)	32	
Superior (%)	1.2	
Complications of diabetes		
With complications (%)	75	
Without complications (%)	16	
Under insulinotherapy (%)	9	
Homocysteine status		
Hyperhomocysteinemia (%)	35.36	
Mean Hyperhomocysteinemia (μmol/L)	14.87±3.29	
Normo homocysteine levels (%)	64.64	
Normal average homocysteine (μmol/L)	7.71±3.40	

51.98±11.70 years in type 2 diabetics without excess weight, and a mean age of 49.64±10.99 years in other type 2 diabetics with excess weight. In our study, as in that of Oga *et al.* [12], the majority of diabetics were between 50 and 59 years old. Furthermore, regarding the distribution of diabetes by ethnic group (Table 1), the Ivorian study conducted by Oga *et al.* [13], which included a male majority, roughly confirmed the proportions of diabetes we obtained (Table 1). The type 2 diabetes is by nature a multifactorial disease involving both genetic and environmental factors. Genetic and

sociocultural differences in diet and lifestyle could explain the ethnic distribution of type 2 diabetes.

Type 2 diabetes was present at all ages and observed at early of age 23 years old. Although type 2 diabetes usually manifests in adults over 40 years, children and adolescents are increasingly being diagnosed with type 2 diabetes due to sedentary lifestyles and the rising prevalence of excess weight in young people [14]. It appears that diabetes occurs at a younger age in Africans than in Caucasians [13, 15]. In our study, a significant difference was found between men and women in

Table 2: Frequency of sports practicing and corresponding average homocysteine levels according to sex and normo- or hyperhomocysteinemic status in type 2 diabetics.

(N=181)	None (sedentary)			Moderate			Intense			P-value
	N	%	Average HCY (μmol/L)	N	%	Average HCY (μmol/L)	N	%	Average HCY (μmol/L)	
Men (N=67)	29	43.30	11.04±4.58	35	52.20	10.69±5.63*	3	4.50	11.56±2.51 *	<0.05
Women (N=114)	56	49.10	9.87±4.89	57	50.00	9.66±4.33	1	0.90	13.77±1.65	ns
General (N=181)	85	46.96	10.41±4.75	92	50.83	10.08±4.90	4	2.21	12.17±2.38	ns
DT2 NHCY (N=117)	52	44.44	7.57±3.79	63	53.85	7.74±3.16	2	1.71	10.11±0.01	ns
DT2 HHCY (N=64)	36	56.25	14.31±2.90	2	40.63	15.68±3.76	2	3.12	14.23±0.33	ns

Note: * – significant difference; ns – non-significant difference; HCY – Homocysteine level; DT2 – type 2 diabetes; HHCY – hyperhomocysteinemic diabetics; NHCY – normohomocysteinemic diabetics.

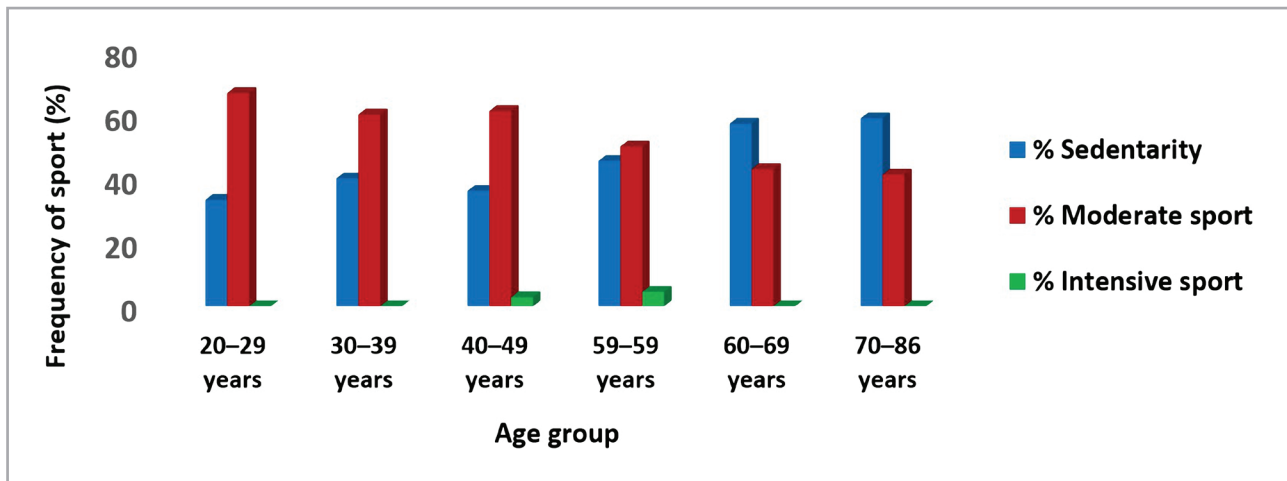


Figure 2: Sports practice among people with type 2 diabetes according to age group.

terms of both age and duration of diabetes, indicating that these factors constitute a risk factor for complications of type 2 diabetes. Indeed, the risk of diabetes increases after 40 years and is aggravated by the risk of insulin resistance [16].

The type 2 diabetics are so susceptible to cardiovascular diseases [17] that the discovery of hyperhomocysteinemia in these subjects constitutes an aggravating factor of diabetes which requires strengthening of dietary and therapeutic measures [18]. The prevalence of hyperhomocysteinemia in our diabetic sample was 35.36%, with a mean hyperhomocysteinemia of 14.87 ± 3.29 $\mu\text{mol/L}$. According to the classification of hyperhomocysteinemias by Faeh et al. [11], this was a moderate hyperhomocysteinemia (12–30 $\mu\text{mol/L}$). Given the particularly harmful nature of hyperhomocysteinemia in diabetics compared to non-diabetics, the pathological threshold in this study was set at

12 $\mu\text{mol/L}$, in accordance with the French Homocysteine Group in 2001 [11]. Indeed, the cardiovascular risk due to hyperhomocysteinemia is already present between 10 and 15 $\mu\text{mol/L}$ [19], well below the arbitrary pathological threshold commonly set at 15 $\mu\text{mol/L}$ in healthy individuals. Moderate hyperhomocysteinemia is generally due to vitamin B deficiencies. According to Demuth [20], moderate hyperhomocysteinemia can have nutritional, pathological, and therapeutic origins. 45.3% of our diabetics had no education. Ignorance and poverty contribute to their high risk of vitamin B deficiencies leading to moderate hyperhomocysteinemia. It is quite possible that unstructured eating habits and an inappropriate lifestyle, specifically sedentary behavior or physical inactivity [21], contribute to the observed moderate hyperhomocysteinemia. Diabetes itself is a cause of hyperhomocysteinemia [22]. Metformin, used in the treatment of diabetes, is also a

Table 3: Frequency of physical activity and corresponding mean homocysteine levels by age group in patients with type 2 diabetes.

Age class (N=181)	None (sedentary)			Moderate			Intense			P-value
	N	%	Mean HCY ($\mu\text{mol/L}$)	N	%	Mean HCY ($\mu\text{mol/L}$)	N	%	Mean HCY ($\mu\text{mol/L}$)	
20-29 years (N=3)	1	33.30	0.50 ± 0.00	2	66.70	7.19 ± 2.33	0	0	0	ns
30-39 years (N=10)	4	40.00	9.43 ± 2.04	6	60.00	9.14 ± 2.38	0	0	0	ns
40-49 years (N=36)	13	36.10	9.21 ± 4.35	22	61.10	8.72 ± 4.45	1	2.80	10.12 ± 0.00	ns
50-59 years (N=66)	30	45.50	11.62 ± 3.19 *	33	50.00	10.96 ± 3.86	3	4.50	12.85 ± 2.39	ns
60-69 years (N=49)	28	57.10	11.61 ± 5.20 *	21	42.90	10.00 ± 6.19	0	0	0	ns
20-69 years (N=164)		46.34	8.47 ± 3.69		51.22	9.20 ± 3.84		2.44	11.48 ± 1.19	ns
70-86 years (N=17)	10	58.80	6.29 ± 5.56 *	7	41.20	12.55 ± 3.71 *	0	0	0	<0.05 *

Note: * – significant difference; ns – non-significant difference; HCY – homocysteine level.

cause of hyperhomocysteinemia due to the depletion of plasma vitamin B stores [23]. Tobacco, coffee, and alcohol also contribute to hyperhomocysteinemia [24]. All of these aforementioned causes, without being exhaustive, could explain the emergence of moderate hyperhomocysteinemias observed in our diabetics.

Homocysteinemia and sports practice in type 2 diabetics

High-intensity physical activity has been implicated as a cause of hyperhomocysteinemia [5]. The impact of physical activity on homocysteine levels varies according to the intensity and the duration. High-intensity physical activity increases the need for B vitamins, decreases their plasma bioavailability, and induces hyperhomocysteinemia [5]. There is a relationship between nutrition, physical activity and homocysteine levels [5]. It was for this reason that we were led to examine, in our diabetic patients, whether their levels of sporting activity constituted specific causes of increased homocysteine levels.

The present study showed that 50.83% of diabetics practiced a moderate physical activity, 2.21% in high-intensity physical activity, and 46.96% were sedentary (Table 2). Regardless of the level of physical activity (none, moderate, or intense), no significant difference in homocysteine levels was observed according to the general context of the 181 type 2 diabetics, the female sex, or the normo- or hyperhomocysteinemic status. The majority of diabetics engaged in moderate exercise: 53.85% in normohomocysteinemic individuals, 40.63% in hyperhomocysteinemic individuals, and 50% in women. According to Duncan *et al.* [25], moderate physical activity is protective against hyperhomocysteinemia, hence the non-significant increase in homocysteine levels observed. Particularly in women, the non-significant increase in homocysteine levels could be explained, on the one hand, by the protective effect of moderate exercise against hyperhomocysteinemia [25], and on the other hand, by the protective effect of estrogen against hyperhomocysteinemia [24]. According to Stanger *et al.* [24], estrogen protects women from hyperhomocysteinemia before menopause; but at menopause, the protective effect of estrogen in women against hyperhomocysteinemia ceases due to its decline. Homocysteine levels in menopausal women then become similar to those in men [24].

Males, however, are not protected from the benefits of estrogen against hyperhomocysteinemia [24]. Homocysteine levels were significantly higher in men

who engaged in more regular and high-intensity physical activity (11.56 ± 2.51 $\mu\text{mol/L}$) compared to those who maintained a moderate level of exercise (10.69 ± 5.63 $\mu\text{mol/L}$). Therefore, intense physical activity, as observed in men, constitutes a specific cause of elevated homocysteine levels.

Our study shows that moderate exercise (50.83%) does not increase homocysteine levels in general, in women, or according to the normo- or hyperhomocysteinemic status. However, high-intensity physical activity significantly increases homocysteine levels, particularly in men. This study is consistent with that of Joubert and Manore [5] and Duncan *et al.* [25].

Unfortunately, in our study, moderate physical activity, recognized as protective against hyperhomocysteinemia according to Duncan *et al.* [24], tends to decrease with age (Figure 2). Several factors could be responsible: the increasing burden of sedentary lifestyles with age (Figure 2), the lack of motivation related to diabetes complications (75% complications and 9% insulin therapy), overweight (44%), obesity (13%) (Table 1), and ignorance of the health benefits of sport.

Furthermore, the study also showed that the different levels of physical activity (none, moderate, intense) across the 20–69 age group had no significant effect on increasing homocysteine levels (Table 3). In the 20–69 age group, the majority of diabetics engaged in moderate physical activity, which is known to be protective against hyperhomocysteinemia, hence the non-significant increase in homocysteine levels.

However, we observed a significant difference between the mean homocysteine levels corresponding to the different levels of physical activity in the 70 and over age group (70–86 years). Homocysteine levels were significantly higher in older adults practicing a moderate exercise (12.55 ± 3.71 $\mu\text{mol/L}$) compared to those who did not (6.29 ± 5.56 $\mu\text{mol/L}$). According to Joubert and Manore [5], high-intensity physical activity is a cause of hyperhomocysteinemia. In these older adults, even a moderate physical activity can be considered as an “intense activity” due to age and decreased physical strength. Furthermore, homocysteine levels increase rapidly after age 65, on average by 10% or 1 $\mu\text{mol/L}$ per year [24]. The significant increase in homocysteine levels with age in diabetics aged 70 to 86 years could be explained, on the one hand, by moderate physical activity which can be considered equivalent to “intense activity” due to age according to Joubert and Manore [5] and, on the other hand, by the physiological decrease in renal function linked to aging according to Stanger *et al.* [24].

This study reveals that moderate physical activity, considered equivalent to “intense activity” in individuals over 70 years of age, is a specific factor in increasing homocysteine levels in Ivorian diabetics. With the exception of individuals aged 70 and over, homocysteine levels generally do not increase during moderate physical activity. Therefore, moderate physical activity, protective against hyperhomocysteinemia, does not constitute a specific cause of elevated homocysteine levels.

Ali et al. [26], reported that 12 weeks of moderate-intensity exercise lowered homocysteine levels. Rendeve et al. [27], reported that walking for 12 weeks reduced homocysteine levels in overweight women with polycystic kidney disease. Vitamin B6, B9, and B12 intake helps maintain healthy homocysteine levels and regulate the demand for these nutrients during exercise, especially when the intensity has increased [5]. Our study corroborates the findings of Rendeve et al. [27] and Joubert and Manore [5]. The 50.83% of diabetic patients who incorporated regular moderate-intensity exercise into their lifestyle showed no risk of hyperhomocysteinemia. At the condition that, they continue to maintain a diet rich in B vitamins and antioxidant nutrients known for their protective effect against hyperhomocysteinemia [24, 28].

According to Nurk et al. [21], a sedentary lifestyle is implicated as a risk factor for hyperhomocysteinemia, similar to vitamin B deficiencies. 46.96% of diabetics did not participate in any sport. They led a sedentary life (Table 3). This sedentary lifestyle was more prevalent in women (49.1%) compared to men (43.3%) (Table 2).

Our study also showed that a sedentary lifestyle increased with age (Figure 2) and significantly raised homocysteine levels in individuals over 50 years of age (50 to 69 years) (Table 3). In individuals under 50 years of age, a sedentary lifestyle in diabetics did not significantly increase homocysteine levels. Glowinska et al. [29] also found no significant gradual increase in hyperhomocysteinemia during the early stages of macrovascular complications of diabetes. This could explain the non-significant increase in homocysteinemia associated with sedentary lifestyles in individuals under 50 years of age. Our study corroborates that of Nurk et al. [21], demonstrating that sedentary lifestyle significantly increases homocysteine levels in individuals over 50 years of age.

The study reveals that sedentary lifestyle (46.96%) in relationship with the age factor (particularly in people over 50) are causes of majoration of homocysteinemia in Ivorians with type 2 diabetes.

A sedentary lifestyle could be linked to undernutrition in the sense of deficiencies and/or insufficient intake of B vitamins and antioxidant nutrients, which are also causes of hyperhomocysteinemia [24]. Furthermore, a sedentary lifestyle could also be linked to overnutrition and lead in the long term to obesity and diabetes. Our sample contained 13.1% obesity (all grades combined) and 44.2% overweight. The progression from obesity to type 2 diabetes involves the oxidation of fats in adipose tissue that overexpresses tumor necrosis factor α (TNF α) and leptin [30]. These two inflammatory factors (TNF α and leptin) are involved in insulin resistance because they inhibit the insulin receptor. They alter the biochemical pathways of post-receptor insulin message transmission and the process of incorporation of glucose transporters into cell plasma membranes [30].

Several studies have confirmed the benefits of lifestyle modifications (physical activity and/or diet) for individuals with type 2 diabetes [31]. Physical activity is generally recommended for people with diabetes. However, it must be adapted to the individual's diabetic profile, taking into account the type, intensity, and duration of the activity [32]. Moderate and regular physical activity can help prevent hyperhomocysteinemia and type 2 diabetes.

Conclusion

Moderate hyperhomocysteinemia is a reality in type 2 diabetics in Côte d'Ivoire. Specific causes of increased hyperhomocysteinemia in Ivorians with type 2 diabetes through physical activity were: high-intensity exercise, particularly in men; moderate exercise in those over 70 years of age, equivalent to intense exercise; sedentary lifestyle (46.96%), particularly in those over 50 years of age; and age in relation with the sedentary lifestyle. Conversely, moderate exercise does not increase homocysteine levels, either across age groups from 20 to 69 years or according to normo- or hyperhomocysteinemic status. Moderate exercise (50.83%) is protective of homocysteine levels and can be recommended for the prevention and treatment of diabetic hyperhomocysteinemia.

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Conflict of interest

The authors declare no conflict of interest.

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