

Diabetes Mellitus and High Blood Pressure: Common Risk Factors, Comorbidities, Nutritional and Dietary Approach

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Abstract

Diabetes mellitus and high blood pressure, chronic diseases affecting more and more people worldwide, have several common risk factors. The coexistence of these diseases in a significant proportion of people increases the risk of complications. Diet and lifestyle are key risk factors on which interventions contribute to reducing or preventing the occurrence or manifestation of other risk factors that also present nutritional issues. In general, diet has beneficial effects on cardiovascular morbidity and mortality, improvement of blood glucose sensitivity, improvement of lipid profile, improvement of blood pressure and reduction of postprandial hyperglycemia. Dietary interventions that have consisted of increasing the intake of micronutrients such as potassium, calcium, magnesium, vitamin A, vitamin D and vitamin C bear witness to this. Antioxidants, namely polyphenols and dietary fiber, are also of interest in increasing insulin sensitivity and reducing blood pressure. Adopting a healthy lifestyle through physical activity, reducing alcohol consumption and smoking cessation improves glycosylated hemoglobin levels and lipid profile. It also decreases abdominal adiposity, insulin resistance, blood sugar and blood pressure. The scientific evidence presented by these numerous studies can be used in the development and/or strengthening of the nutritional and dietary management of diabetes mellitus and high blood pressure.

Keywords

Diabetes Mellitus, High Blood Pressure, Micronutrients, Antioxidants, Lifestyle

1. Introduction

Noncommunicable diseases are increasingly a global burden with enormous health, socio-economic and psychosocial consequences [1]. Among these non-communicable diseases are diabetes and high blood pressure, which affect many people. Indeed, the global prevalence of high blood pressure in 2019 was 33% in the population aged 30 to 79 years [2]. As for diabetes, its global prevalence in 2021 was 6.8% in the population aged 20 to 70 years [3]. In 2023, non-communicable diseases were responsible for an estimated 41 million deaths worldwide, with a significant share of those due to diabetes and high blood pressure [1]. An estimated 300 million people are expected to be diabetic by 2025 and 33% of early deaths are expected to be due to noncommunicable diseases. In addition to this, diabetes would be the seventh leading cause of death in the world by 2030 [4]. At the present stage, if the medical and pharmacological management of the disease are making major progress, the nutritional and dietary approach is not yet being taken into account in many countries, in this case those in the developing world. Nutritional and dietary sciences can be further leveraged for greater effectiveness in the fight against diet-related diseases. A synthesis of the work already carried out is therefore necessary to better guide nutritional and dietary management interventions for diabetes mellitus and blood pressure. In this work, we will first talk about the common risk factors for diabetes mellitus and high blood pressure, then about their comorbidities and finally about the contribution of diet and a healthy lifestyle to their management.

2. Common Risk Factors for Diabetes Mellitus and High Blood Pressure

2.1. Genetic and Epigenetic Factors

The predisposition to develop type 1 diabetes has been established in people with at least one diabetic parent. It is estimated that there is a 30% and 70% risk of developing diabetes mellitus if you have 1 and 2 diabetic parents respectively. Among people with type 1 diabetes, 6% to 10% have a family history and are twenty times more exposed to the pathology compared to the general population. Transmission is hereditary polygenic [5] [6]. Genetics through several means has identified the genes involved in the monogenic and polygenic forms of type 1 diabetes and type 2 diabetes [7]. The form of type 2 diabetes is said to be monogenic when it is caused by mutations in a single gene with a major role in beta-pancreatic cells. Conversely, the polygenic form results from the interaction of multiple genetic mutations in several genes [8].

The genetic predisposition to high blood pressure has been proven through several family-wide studies. The involvement of genetic factors in the manifestation of high blood pressure is estimated at between 30% and 50% [9]. Studies support that high blood pressure in grandparents as well as parents is associated with an increased risk for the third generation of also having high blood pressure [10]. In addition to this, 30% of the variance in high blood pressure is thought to be genetic

in origin [11]. In a Dutch population, a study conducted in 2007 found significant heritability estimates for systolic blood pressure ranging from 0.24 mmHg to 0.37 mmHg [12].

These various types of studies confirm that genetic and epigenetic factors are risk factors for these diseases in several scenarios. Improved identification of genes that takes into account the diversity of breeds could be of great value in enhancing the management of these conditions.

2.2. Age

The risk of developing type 2 diabetes increases sharply with age. Beyond the age of 65, 10% to 15% of subjects develop it. The progressive decrease in beta cell function leads to a deficit in insulin secretion [13]. Aging is also accompanied by a progressive decrease in insulin secretion, a reduction in muscle mass that is the main user of glucose, and a probable reduction in insulin sensitivity. These physiological changes may contribute to the onset of type 2 diabetes, with an annual change in exposure of 7% [13] [14]. Type 1 diabetes, on the other hand, in view of its pathophysiology, is diagnosed in the minority before the age of 20 and mostly before the age of 40 [13]. Age was revealed as the main risk factor in a study conducted in 2022 of hospitalized people with type 1 diabetes at the Mohamed Bou-diaf Hospital in Ouargla, southern Algeria. In this study, 43.8% of patients were at least 46 years of age [15]. A prevalence of 6.8% of type 2 diabetes in people aged 0 to 54 years compared to 54.2% in people aged 55 and over was revealed in 2021 by a study conducted in the Grand-Est region of France [16].

Age is also a risk factor for high blood pressure. The positive association between age and high blood pressure has been proven in several studies. Results from a 2011 study conducted among the general population in Lomé, Togo, revealed that the prevalence of high blood pressure was 8.8% in subjects aged 15 to 24 years and 70% in subjects over 60 years of age [17]. Among textile workers in Kisangani in the Democratic Republic of Congo, a study conducted in 2020 supported that the level of significance between age and high blood pressure increased in tandem [18]. Data collected over 8 years in the Chinese population showed a continuous evolution of systolic blood pressure between the ages of 30 and 79 [19]. A study of Canadian populations based on health data from 2012 to 2015 found that people aged 70 to 79 are twice as likely to develop high blood pressure as those aged 40 to 59. Indeed, 71% of men and 69% of women in the age group of 70 to 79 years old were hypertensive compared to 25% of men and 21% of women in the age group of 40 to 59 years old [20].

The pathophysiology of these diseases best explains why age is one of their common risk factors: advanced age for type 2 diabetes and high blood pressure, and, conversely, a young age for type 1 diabetes.

2.3. Overweight and Obesity

Obesity is an important risk factor for the development of type 2 diabetes. In fact,

80% of people affected by type 2 diabetes are overweight in varying proportions, capable of inducing or aggravating insulin resistance through permanent hypersecretion of insulin to regulate blood sugar levels [21]-[23]. In addition, the abdominal form of obesity, a long period of exposure to excess weight and/or rapid weight gain, promotes insulin resistance, deterioration of carbohydrate tolerance and degradation of beta cells [21]-[23]. The release of a large amount of free fatty acids from visceral adipose tissue transported to the liver leads to an overproduction of glucose and a synthesis of triglycerides. As circulating fatty acids have increased, their use is prioritized at the muscle level with a decrease in glucose storage and utilization [21]-[23]. The increase in hepatic glucose production therefore determines the rise in fasting blood glucose due to insulin resistance and high glucagon production. [21]-[23]. Blood sugar level increases as body mass index increases until severe obesity [24]. In Côte d'Ivoire, a study carried out in 2017 among diabetics aged 20 to 79 revealed that 49.74% were overweight [25]. Of the patients newly diagnosed with diabetes mellitus in 2019 at the National Diabetes Center in Bamako, Mali, 32% were overweight and 24% were obese [26].

Overweight and obesity, including abdominal obesity, have a clear causal link with glucose intolerance, dyslipidemia, inflammation and blood pressure. They are thought to have the most negative influence on blood pressure compared to other risk factors and are also the most important risk factor for cardiovascular disease. Indeed, the more weight the subject gains, the more he or she is exposed to a risk of increasing his or her blood pressure and therefore to the onset of high blood pressure. Weight loss therefore promotes a significant drop in blood pressure in a good majority of subjects [27]. A study in a young adult population in southern Mexico found that obesity, including abdominal obesity, is associated with high blood pressure, in addition to other metabolic disorders. The same study found that the increase in blood pressure evolved in tandem with the level of obesity [28]. Another study carried out in 2015 among adult workers in Kinshasa, DRC, reveals that people suffering from obesity, including abdominal obesity, were 5 times more likely to suffer from high blood pressure [29]. A study conducted among workers at the Abidjan Autonomous Port in Côte d'Ivoire reveals that the prevalence of high blood pressure was more significant among obese people than among other groups of people in 2001 [30].

The metabolic disorders caused by being overweight and obesity explain why these conditions are more commonly associated with diabetes mellitus and high blood pressure, regardless of race, gender, or geographic location.

2.4. Dyslipidemia

Dyslipidemia is generally manifested by an increase in blood levels of triglycerides, low density lipoprotein (LDL) and a decrease in blood levels of high density lipoprotein (HDL) and therefore an increase in total cholesterol [31]. Patients with type 2 diabetes also have dyslipidemia in the majority of cases. Hypertriglyceridemia and low levels of high-density lipoprotein cholesterol (HDL-c) are the

dyslipidemias encountered in diabetic subjects. The level of low-density lipoprotein-cholesterol (LDL-c) increases slightly or remains static. Indeed, insulin resistance or its secretory deficiency would modify lipid metabolism, thus promoting the occurrence of cardiovascular diseases [32]. In addition to this disruption of lipid metabolism, the lipid profile of the diabetic subject is essentially made up of very low-density lipoprotein (VLDL), LDL and HDL enriched with triglycerides. Oxidation of LDL and glycation of apolipoproteins also mark this lipid profile [33]. In Senegal, a study published in 2010 revealed that among diabetics, 43.1% suffered from dyslipidemia. These dyslipidemias were characterized by 47.4% hypertriglyceridemia, 32.8% mixed dyslipidemia, and 19.7% hypercholesterolemia [34].

Dyslipidemias represent abnormal levels of different forms of lipids in the blood. Dyslipidemia can affect one or more of the forms of lipids, namely LDL-c, HDL-c, CT, and triglyceride [35]. High blood pressure is often accompanied by dyslipidemias favorable to the occurrence of atherosclerosis. In several studies, an increase in blood pressure was observed as blood cholesterol levels increased [36]-[38]. A meta-analysis of a population of 37,902 people from 10 African countries found that people with high blood pressure were 2.32 times more at risk of dyslipidemia than people without high blood pressure [39]. A study in Nigeria in 2009 found that 86.2% of adult hypertensive people in the city of Abuja had at least one form of dyslipidemia. These dyslipidemias were manifested by blood levels of low HDL-c, high LDL-c, high total cholesterol, high triglyceride, and both high total cholesterol and triglyceride [40]. In 2023, it was proven in a young adult population in Poland that high blood pressure was associated with abnormally high total cholesterol, LDL and triglyceride values [41]. A retrospective observational study conducted in Ancona, Italy, involving data from 1,219 patients seen between May 2013 and May 2018, showed that 91.1% of people with high blood pressure also had at least one form of dyslipidemia [42].

The prevalence of dyslipidemia is high among people with diabetes and those with hypertension. These conditions may occur individually or in combination and increase cardiovascular risk.

2.5. Sedentary Lifestyle

The development of motorized means of transport, the mechanization of work, urbanization and preferred forms of leisure considerably reduce the level of physical activity of the population. Indeed, reducing the level of physical activity reduces the use of glucose and leads to an increase in its blood concentration [43]. A sedentary lifestyle exposes you to hyperglycemia and cardio-metabolic risks. Positive associations between time spent sitting and the risk of premature death in people with diabetes have been revealed through observational systematic reviews [44]. A 2022 study of people 18 years of age and older in the city of Ouagadougou in Burkina Faso found that 68.75% of diabetics were sedentary [45].

A sedentary lifestyle involves low energy expenditure that can lead to an in-

crease in total fat mass, visceral fat deposits, blood lipid concentration and inflammation [46]. A sedentary person is therefore more exposed to the risk of developing high blood pressure compared to an active person [47]. In southern Algeria in 2020, a study found a significant difference in the prevalence of high blood pressure between active people (32%) and sedentary people (44.7%) [48]. At the end of a study conducted in 2019 and involving hypertensive Central African subjects, it appears that 34.3% were sedentary [49]. Among hypertensive elderly subjects in Nouakchott, Mauritania, 40% of men and 60% of women were sedentary during 2019 [50]. A meta-analysis argues that an extra hour per day in a sedentary situation increased systolic blood pressure by 0.06 mmHg and diastolic blood pressure by 0.2 mmHg in adult populations but also in adolescents [51]. In prolonged and uninterrupted sitting, minimal and slightly significant increases in systolic blood pressure were also reported by meta-analysis. These increases were minimal and not significant for diastolic blood pressure. The interruption of prolonged sitting led to a significant decrease in systolic blood pressure, unlike diastolic blood pressure, which did not decrease significantly [52].

A sedentary lifestyle contributes to being overweight, obesity, and the accumulation of sugars and fats, all of which significantly increase the risk of diabetes and high blood pressure.

2.6. Alcohol and Tobacco Consumption

Alcohol influences blood sugar control and glucose production [53]. High alcohol consumption is strongly associated with insulin resistance and the risk of developing diabetes mellitus [54] [55]. It also exposes it to metabolic/cardiovascular complications once diabetes mellitus sets in [55] [56]. In a Swedish population consisting of people with normal blood sugar levels and prediabetic people aged 35 to 56, it has been proven that heavy alcohol consumption increases the risk of blood sugar disorders. In fact, in this study, men who consumed beer and spirits were respectively 1.8 times and 2.03 times more exposed to a risk of type 2 diabetes compared to those who did not [57]. A meta-analysis of 20 studies showed a U-shaped relationship between alcohol consumption and diabetes mellitus risk. It also revealed that from a little more than 60 g/day, alcohol consumption increased the risk of type 2 diabetes [58].

The risk of developing type 2 diabetes increases in people who smoke by about 40%. Smoking promotes the development of abdominal obesity due to the toxic effect of nicotine on the pancreas and insulin receptors. This toxic effect leads to insulin resistance and therefore hyperglycemia [59]-[61]. Chronic inflammation and an unhealthy lifestyle in people who smoke can also promote the development of type 2 diabetes [59]. Other studies explain that nicotine, which is highly toxic, leads to an alteration of beta cells and their functions. This manifests itself in disorders of insulin production and glucose regulation. In addition, by activating oxidative stress, nicotine induces insulin resistance [60] [62] [63]. The acute alteration of carbohydrate tolerance and the increase in insulin resistance was high-

lighted by a study in both smokers and non-smokers after consumption of three cigarettes [60] [62] [63]. The risk of chronic degenerative complications and mortality increases with smoking in people with diabetes [59] [61] [64]. Several meta-analyses also confirm a high relative risk of all-cause mortality in diabetics who smoke compared to those who do not smoke [64].

Alcohol consumption is involved in the occurrence of high blood pressure. Increased blood pressure has been found to be associated with frequent alcohol consumption across several studies [65]. Indeed, alcohol disrupts the functioning of the central nervous system, increases cortisol levels, stimulates the renin-angiotensin-aldosterone system and stimulates the endothelium to release vasoconstrictors. It is also responsible for the deficiency of baroreceptors, the increase in the activity of the sympathetic nervous system but also the increase in vascular reactivity. It also leads to a loss of endothelial relaxation, and an increase in angiotensin II [65]. One study showed that in subjects at least 60 years of age, daily consumption of at least 1 glass of alcohol increased diastolic blood pressure compared to non-drinkers. Randomized clinical trials have concluded that consumption of no more than 30 g per day increases blood pressure [65]. The involvement of cigarette consumption in the occurrence of high blood pressure has been proven by a study carried out in several racial and ethnic populations in America [66]. Its consumption would induce a release of norepinephrine at the level of the adrenergic nerve endings because of nicotine. It is not a major risk factor because there seems to be an inverse long-term relationship between it and high blood pressure [67].

Alterations in carbohydrate and lipid metabolism, impaired pancreatic beta-cell function, increased arterial stiffness, and disruption of the nervous system are among the harmful effects of alcohol and tobacco use that contribute to the development of diabetes mellitus and hypertension.

2.7. Unbalanced Diet

Excessive consumption of sugar and saturated fats promotes weight gain and disorders of lipid metabolism, all of which are risk factors for the development of diabetes mellitus, particularly type 2 diabetes [68]. Other studies also support the fact that ultra-processed foods, foods high in trans fats and low in dietary fiber also promote the onset of diabetes mellitus [69]. This is because excessive intake of saturated fatty acids causes hypertriglyceridemia, hypercholesterolemia, and insulin resistance [70]. A longitudinal study carried out over 7 years in the NutriNet-Santé cohort in France found that a high intake of total fatty acids and trans fatty acids increases the risk of type 2 diabetes [71]. Another study from the same cohort conducted over 4.8 years found that people who consumed more dietary fiber had a reduced risk of developing type 2 diabetes compared to those who consumed less [71]. Hyper-carbohydrate and hyper-lipid intakes of 25% and 32% respectively were revealed in hospitalized diabetics at the end of a study in Tunis, Tunisia. This study also found that 70% and 23% of patients had an inadequate

intake of mono- or polyunsaturated fats, respectively. In addition to this, 95% of patients had inadequate vitamin D intake, 60% inadequate vitamin C intake, 58% inadequate vitamin B12 intake, and 50% inadequate vitamin B9 intake [72]. A meta-analysis that included several WHO regions and studies conducted between 1998 and 2023 revealed high prevalences of certain micronutrient deficiencies in people with diabetes. These prevalences were 60.45% for vitamin D, 41.95% for magnesium, 27.81% for iron and 22.01% for vitamin B12 [73].

The quality of the diet is a major risk factor in the occurrence of high blood pressure. The Intersalt study highlighted the involvement of excessive sodium consumption in the occurrence of high blood pressure in salt-sensitive subjects [74]. The cardiovascular diseases and alimentary comparison study (Cardiac) also supports the involvement of sodium in the occurrence of high blood pressure after finding a correlation between urinary sodium excretion and systolic blood pressure or diastolic blood pressure [75]. Several other studies have also demonstrated the involvement of excessive sodium intake in the occurrence of high blood pressure [76]-[78]. Indeed, excessive sodium consumption increases blood volume and blood pressure through water retention due to the concentration of sodium ions (Na⁺) in the serum [79]. The increase in Na⁺ in people with normal blood pressure induces hemodynamic changes that tend to keep blood pressure constant. These changes are manifested by the reduction of the resistance of the renal and peripheral vessels and an increase in the production of nitric oxide, which is a vasodilator [79]. Excessive sodium consumption also leads to stiffening of the arteries and vasoconstriction [80]. Nowadays, sodium intake comes mainly from industrial foods and a minority from the addition of salt in preparations or meals at the table. Although the consumption of processed foods has increased, their high sodium levels are unknown to the general public. [81]. Deficiencies in certain micronutrients such as potassium (K), calcium, magnesium (Mg), and dietary fiber have been significantly associated with high blood pressure in a Tunisian population [82]. High fat intakes also promote the onset of high blood pressure. Indeed, the consumption of fats such as butter, lard, margarine and the high consumption of oils expose the subject to the occurrence of high blood pressure [83].

This summary of the facts presents diet as a risk factor for which interventions are essential—not only to prevent or reduce the manifestation of other risk factors but also to reduce cardiovascular risk.

2.8. Diabetes Mellitus, High Blood Pressure and Ultra-Processed Foods

Food additives (some emulsifiers), neoformed compounds (acrylamide, acrolein, industrial trans fatty acids) and packaging contaminants (phthalates, bisphenols) contained in ultra-processed foods pose health risks [84]. The consumption of ultra-processed foods exposes you to the risk of overweight, obesity, high blood pressure, dyslipidemia, cancer, cardiovascular disease and type 2 diabetes. It also exposes people to depressive symptoms, a higher frequency of irritable bowel syn-

drome and mortality. These results have been revealed by cohort studies in specific and/or general populations in Spain, Brazil, France and many other countries [84].

Ultra-processed foods are implicated in the onset of diabetes mellitus due to their high glycemic load causing a rapid and significant rise in blood sugar levels. Frequent and repeated elevations in blood glucose lead to insulin resistance resulting from a continuous loss of cell sensitivity to insulin action [85]. This disrupts carbohydrate homeostasis and promotes the elevation of glucose in the blood and the storage of a large quantity [85]. Studies on the composition of 135 ultra-processed foods show that the hyperglycemic potential increases with the level of processing of the food, all crowned by reduced satiability [86]. The low content of ultra-processed foods in minerals, vitamins and dietary fiber contributes to chronic inflammation and metabolic dysfunction promoting more development of type 2 diabetes [84] [85]. In the UK, a significant increase in the risk of type 2 diabetes was found whenever the consumption of ultra-processed foods increased by 10% in a population aged 40 to 69, followed over approximately 5.4 years, without diabetes and consuming an average of 22.1% ultra-processed foods at the start of the study. At the end of the follow-up, it also appears that 1.4% of the people followed have become diabetic [87]. The overconsumption of ultra-processed foods is also implicated in the occurrence of overweight and obesity, which are risk factors for diabetes mellitus. In France, a follow-up of more than 100,000 people over 5 years shows that the risk of type 2 diabetes increased significantly when the consumption of ultra-processed foods increased by 10% [71]. The risk of developing obesity and dyslipidemia, all risk factors for diabetes mellitus and high blood pressure, has been higher in people who regularly consume ultra-processed foods [86].

Several studies explain the involvement of ultra-processed foods in the occurrence of high blood pressure. Ultra-processed foods contain high levels of sugars, saturated fatty acids and trans fatty acids, but low levels of protein, micronutrients and dietary fiber. Intake in large quantities exposes subjects to the risk factors for high blood pressure and therefore to its occurrence [88]. The 2015 Canadian Community Health Survey reports that people whose consumption of ultra-processed foods accounted for 73% of total energy intake were 1.6 times more likely to develop high blood pressure than those whose consumption of ultra-processed foods accounted for 24% of total energy intake [89]. Significant variations in systolic blood pressure and diastolic blood pressure between groups of people with the lowest share of ultra-processed foods and those with the highest share of ultra-processed foods were observed in a study conducted in southern Brazil in 2010 among hypertensive patients aged 30 to 80 years. Differences in systolic blood pressure were 11.8 to 19.8 mmHg and those in diastolic blood pressure were 4 to 8.3 mmHg [90]. Results from a longitudinal study in a Brazilian population aged 35 to 75, followed over an average of 3.9 years, support that the risk of high blood pressure increased with the level of consumption of ultra-processed foods [91]. A cohort

study conducted in Tehran, Iran, found a 48% risk of developing high blood pressure in people who consumed more ultra-processed foods compared to those who had the lowest share of ultra-processed foods [92]. A meta-analysis that included cohort studies and cross-sectional studies found a significant association between high consumption of ultra-processed foods and the incidence of high blood pressure in adults [88].

The role of ultra-processed foods in the development of these diseases is increasingly well documented by numerous studies, which can be used to develop public health and/or clinical interventions.

3. Comorbidity of Diabetes Mellitus and High Blood Pressure

Type 2 diabetes and high blood pressure frequently coexist in some people. A cumulative effect of the risk factors for both diseases is observed in patients with this clinical profile, increasing the risk of macroangiopathic and microangiopathic complications. [93]-[99]. In fact, insulin sensitivity and insulin resistance contribute to obesity and dyslipidemia. They cause an increase in cardiac output and peripheral vascular resistance, which contribute to the development of high blood pressure [100] [101]. High blood pressure, characterized by vascular dysfunction and lesions, exacerbates the metabolic abnormalities associated with diabetes mellitus and accelerates the onset of cardio-renal diseases [102]-[104].

Several epidemiological studies around the world testify to the coexistence of diabetes and high blood pressure. Within a Tunisian population with diabetes followed in a health service, 48.8% of diabetics were also hypertensive. Of these people who were both diabetic and hypertensive, 33.3% suffered from ocular complications and 20.2% from kidney complications. The prevalence of degenerative complications was also higher in these disorders than in diabetics without high blood pressure [105]. Another study carried out in Senegal in 2007 among a layer of people with a comfortable socio-economic status shows that 43% of people affected by type 2 diabetes also suffered from high blood pressure [106]. High blood pressure supports diabetic nephropathy in the case of type 1 diabetes, unlike in the case of type 2 diabetes where it is essential. In most cases, high blood pressure precedes the diagnosis of diabetes [107] [108]. Among the diabetic population of the city of Saint Louis in Senegal in 2010, 87.8% also suffered from high blood pressure [109]. In semi-rural Senegal, a study reported a significant association between high blood pressure and diabetes in 2021 [109]. A 2019 study conducted in Mali among people with type 2 diabetes found that 64.9% also had high blood pressure [110]. At the Kindia Regional Hospital in Guinea Conakry in 2018, 48% of people with diabetes also suffered from high blood pressure [111]. In Niger, among diabetics over 60 years of age consulted in 3 hospitals in Niamey, 75.2% also suffered from high blood pressure [112]. In the communes of the province of Zon-doma in Burkina Faso, the prevalence of high blood pressure was 23.6% among people with diabetes aged 16 years and older in 2015 [113]. A study carried out in

2020 in the city of Ouahigouya in 2022 with regard to subjects aged 18 and over showed that 58.33% of diabetics were also hypertensive [45]. Higher rates of cardiovascular death, stroke, myocardial infarction, angina, and amputation were observed in diabetic patients with hypertension compared to those without hypertension in a study conducted in the United States of America. [114] In Thailand, a nationwide study conducted in 2015 reported that people with diabetes and hypertension were 1.32 times more likely to develop microvascular complications than those with diabetes and normal blood pressure, with a high level of statistical significance ($p = 0.001$) [115].

Given the existing data on the comorbidity of these conditions, treating one of them should serve as a preventive measure for the other, in order to reduce the occurrence of complications and improve patients' overall health.

4. Contribution of Diet and Lifestyle to the Management of Diabetes Mellitus and High Blood Pressure

4.1. Interest of the Diet

Diet contributes to lower blood sugar levels [116]. It also improves blood pressure and slows the development of high blood pressure. [117] [118]. It has shown beneficial effects on cardiovascular morbidity and mortality, improvement of blood glucose sensitivity, improvement of lipid profile and attenuation of postprandial hyperglycemia [119]. In addition to diet, studies support that promoting a healthy lifestyle through physical activity, reducing alcohol and tobacco consumption also contributes to the proper management of chronic diseases such as diabetes mellitus and high blood pressure [120] [121].

For diabetics, WHO and FAO advise intakes of less than 10% of saturated fat. They also recommend high dietary fiber intake through the consumption of whole grains, legumes, vegetables and fruit [116]. Nutritional interventions aimed at reducing the progression of high blood pressure have shown beneficial effects, especially with the implementation of the dietary approach to stop hypertension (DASH) diet [122]. DASH is based on a low intake of red meat, sugar, fat, salt, and a high intake of vegetables, whole grains, and low-fat dairy products [123].

Consumption of unprocessed or minimally processed foods results in a better insulin response than consumption of processed foods with a modified physical structure [124]. The consumption of whole grains, for example, is presented as favorable to the prevention of chronic diseases, unlike refined cereals that can promote the onset of type 2 diabetes [125]. Reducing sodium intake has been shown to be beneficial in lowering blood pressure in countries such as Portugal, China, Belgium and Japan after trials of several diets over long periods of time in communities [75].

4.2. Potassium, Calcium and Magnesium Intake

Potassium (K), calcium (Ca) and magnesium (Mg) have been known to have natriuretic effects. These micronutrients, in addition to their vasodilatory effect, are

thought to act on renin and angiotensin II [126] [127].

Potassium is involved in several vital functions of the body such as muscle contraction, fluid homeostasis and blood pressure reduction [127]. Potassium intakes reduce blood pressure through vasodilation following the endothelial production of nitric oxide [128]. Potassium also reduces blood pressure through the elimination of sodium and water through the urinary tract and its antihypertensive power is thought to be a function of sodium intake [80] [129]. The prospective urban rural epidemiology (PURE) study, which involved 100,000 subjects from 18 countries, supports that potassium intake is associated with a decrease in systolic blood pressure in hypertensive subjects, especially the elderly. The increased risk of developing high blood pressure was also highlighted in subjects with low potassium intake through a sub-analysis of the Prevention of Renal and Vascular Endstage Disease (PREVND) study [130]. Some studies argue that decreasing the sodium-to-potassium (Na/K) ratio and increasing potassium intake correlate significantly with decreasing blood pressure. In fact, about fifteen randomized controlled trials of potassium supplementation in hypertensive patients who did not adhere to antihypertensive therapy showed a 6.8 mmHg reduction in systolic blood pressure and a 4.6 mmHg reduction in diastolic blood pressure [131]. Another study in Southern California in 584 men and 718 women between the ages of 30 and 70 also showed a strong correlation between Na/k and lower blood pressure [130]. A study of 24,096 Korean adults aged 19 and over found that an intake of 1 mg of potassium reduced blood pressure by 1.01 mmHg [132]. The WHO recommendation on potassium intake in adults is 3.5 g/day to reduce blood pressure, the risk of cardiovascular disease, stroke and coronary artery disease [133]. In varying proportions, potassium is present in whole grains, legumes, fruits, vegetables, meat products, milk and dairy products [127].

Calcium helps to increase HDL levels and conversely decrease LDL levels. This leads to a reduction in fat mass. The decrease in its concentration has a vasodilatory effect on the relaxation of vascular fibers and can also increase the excretion of sodium [80] [134] [135]. Calcium intake also regulates blood pressure through the increase of intracellular calcium in the smooth muscles of blood vessels leading to vasoconstriction [134]-[136]. A meta-analysis of randomized controlled trials showed reductions of 2.63 mmHg and 1.3 mmHg in systolic blood pressure and diastolic blood pressure respectively for daily supplementation of 1.2 g in people with a daily intake of less than 0.8 g [137]. Two meta-analyses from 1996 and 2006 reported only a decrease in systolic blood pressure in hypertensive people with an increase in calcium intake [138]. Reductions of up to 4.45 mmHg for systolic blood pressure and 1.16 mmHg for diastolic blood pressure have been reported by results from several other systematic reviews in both normotensive and hypertensive patients with calcium supplementation [139].

Magnesium ensures the transport of calcium and potassium ions and is essential for the operation of the Na⁺/K⁺ pump. It also contributes to the regulation of potassium through the decrease in renal excretion of potassium. A lack of intake

naturally has an impact on the use of these nutrients in the body [135] [140]. In addition to this, an increase in magnesium intake decreases vasoconstriction and vascular resistance [80] [135]. The decrease in blood pressure through an increase in magnesium intake has been experimented with in rats. However, magnesium works synergistically with calcium to induce vasodilation that is conducive to lowering blood pressure [80]. Magnesium also has anti-inflammatory and antioxidant effects on the vascular system. A high intake of magnesium could decrease the thickness of the blood vessel media and lead to vascular hypotrophy followed by a drop in blood pressure [135]. A deficit in Mg intake was correlated with complications of type 2 diabetes such as high blood pressure, macro and microangiopathies in two hospital facilities in Mali after follow-up of patients over the course of 12 months [141]. Another study, in Algeria, among hospitalized diabetics revealed that 57% of patients with Mg deficiency also suffered from high blood pressure [142]. A high frequency of Mg deficiency was also highlighted by a study carried out in a hospital in Ouagadougou, Burkina Faso [143]. These studies show the importance of Mg in the nutritional management of diabetes mellitus and high blood pressure, although for the moment few studies take into account the amount of intake.

Numerous studies have identified these minerals as being of interest in the pathogenesis and management of diabetes mellitus and hypertension. The many and varied studies conducted among different groups of people of various races across different geographic regions—which have yielded mixed results—warrant further investigation to continuously improve the quality of nutritional care and public health interventions.

4.3. Vitamin and Antioxidant Intake

The antioxidant power of food is recognized for its protective effect against cancer, CVD and other chronic diseases through several epidemiological studies. Antioxidants, in addition to neutralizing free radicals, inhibit their formation. They improve the body's defense capacity and repair the damage caused by free radicals [144]. Micronutrients such as vitamin A, vitamin D, vitamin C and vitamin E, copper, zinc, selenium, manganese, iron have antioxidant capacities. The same is true for certain secondary metabolites such as flavonoids and polyphenols [145] [146]. The high urinary excretion in diabetics is coupled with a high loss of micronutrients and therefore a reduction in plasma levels of micronutrients. This disrupts micronutrient homeostasis and increases the need for micronutrient intake [147].

Vitamin A, by co-acting with singlet oxygen, prevents the oxidation of many biological molecules, including polyunsaturated fatty acids. The beta-carotene form is the most effective [146]. It also captures hydroxyl radicals and peroxy radicals and is thought to inhibit lipid peroxidation chains [144]. Vitamin D modulates inflammation, adaptive immunity, and has an anti-inflammatory effect in patients with type 1 diabetes. It would improve insulin sensitivity and prolong the life of beta-pancreatic cells by protecting them from apoptosis [146]. Vitamin D also helps to

reduce blood pressure. A 6.13 relative risk of the incidence of high blood pressure in men with inadequate serum vitamin D levels compared to those with normal levels was reported in a 4-year prospective study. This risk was 2.67 in women [148]. Vitamin C fights oxidative stress through the scavenging of hydroxyl radicals, superoxide anions of hydrogen peroxide, reactive nitrogen species and singlet oxygen. It contributes to the regeneration of vitamin E and protects membrane phospholipids from peroxidation damage [144] [149] [150]. The daily intake of 1,000 mg vitamin C has been shown to be beneficial for reducing blood sugar and lipids in people with type 2 diabetes through a study in Iran [151]. Other studies have also proven that Vitamin C improves control of blood sugar, lipids and serum insulin [146]. Vitamin E prevents the spread of lipid peroxidation caused by oxidative stress by inserting itself into cell membrane fatty acids and lipoproteins [144] [146].

Studies support that antioxidants increase insulin sensitivity, prevent tissue oxidation, enhance insulin action through the activation of insulin receptors, and serve as a component in glucose metabolism [147]. Polyphenols reduce the absorption of simple sugars and improve glucose absorption at the muscle and adipocyte levels. They would also protect beta-pancreatic cells from glucose toxicity and improve insulin secretion [135]. Polyphenols impact blood sugar levels by inhibiting glucose absorption in the intestine or peripheral tissues [152]. They optimize endothelial function and increase the bioavailability of nitric oxide, which is a vasodilator. They also act on lipid metabolism, inflammation and preserve cellular antioxidant capacity [150].

These encouraging results highlight the importance of vitamins and phytonutrients in the nutritional management of diabetes mellitus and hypertension. However, several avenues remain to be explored to better identify the various phytonutrients, understand the mechanisms of action of vitamins and phytonutrients, and quantify the threshold intakes at which their effects become apparent.

Dietary fiber has been shown to reduce blood pressure and increase insulin sensitivity [117]. Results of a meta-analysis of randomized studies published in PubMed between January 1, 1980 and December 31, 2010 report a significant improvement in blood glucose levels when dietary fiber intakes are increased. The average amount of dietary fiber consumed in this study was 18 grams/day (g/day) [153]. A study in patients with type 2 diabetes found that high dietary fiber intakes were beneficial. This study subjected 13 patients to two types of diets with the same energy value but with moderate and high levels of natural dietary fiber, respectively. The high-fiber diet reduced plasma concentrations of LDL-c, triglyceride and total cholesterol more compared to the low-fiber diet. It also most decreased the absorption of cholesterol at the stomach and intestinal level. The excretion of acid sterols was also increased by the diet richer in dietary fiber [154]. Other metanalyses have also shown a significant reduction in the incidence of diabetes (15% to 19%) in people with type 2 diabetes with high dietary fiber intakes compared to those with low intakes in American populations [155]. Large-scale,

prospective cohort studies show that high intakes of AF, especially insoluble AF from cereals, reduce insulin resistance and the risk of developing type 2 diabetes by 20% - 30% [156]. A longitudinal cohort study that collected data from American adults with diabetes and prediabetes from 2011 to 2018 showed a significant association between high dietary fiber intake and reduced risk of all-cause mortality [157]. The major sources of dietary fiber are whole grains, legumes, fruits and vegetables [156].

The challenge with dietary fiber lies in estimating the appropriate amount to provide for all possible patient scenarios—that is, patients with diabetes and/or hypertension, with or without risk factors. Such studies will undoubtedly improve the quality of patients' nutritional care.

4.4. Physical Activity

Physical activity reduced blood sugar and blood pressure. Physical activity has been shown to improve cardiorespiratory health and physical endurance in diabetics. It would also allow better control of blood sugar, a reduction in insulin resistance, the improvement of the lipid profile, the lowering of blood pressure and the maintenance of weight loss [44]. Improvements in glycosylated hemoglobin, triglycerides, and cholesterol were found in patients with type 2 diabetes after supervised exercise compared to control groups who did not exercise [44]. Regular physical activity has also been associated with a decrease in cardiovascular mortality and overall mortality in patients with type 1 and type 2 diabetes in cohort studies [44]. Physical activity also contributes to the lowering of blood pressure. Randomized controlled trials have shown that a modest weight loss of 3 to 9% leads to a significant reduction in systolic blood pressure and diastolic blood pressure of 3 mmHg in overweight people [158]. In addition, depending on the type of physical activity conducted, a decrease in blood pressure and/or hypotension is observed that can last about 22 hours after physical effort [159]. Physical activity also helps to increase HDL-c levels, but also to reduce the effects of high blood pressure, obesity and tobacco use [160]. It also improves lipid profile, decreases, abdominal adiposity, blood pressure and insulin resistance [27].

Physical activity remains an essential part of a healthy lifestyle, not only for healthy individuals but also for those with medical conditions.

4.5. Reducing Alcohol and Tobacco Consumption

Moderate alcohol consumption is associated with a decreased incidence of diabetes mellitus and cardiovascular disease in diabetics [161]. A prospective study of 38,564 diabetic patients from 1994 to 1997 found that blood glucose and glycated hemoglobin (HbA1c) levels decreased with low alcohol consumption [162]. In subjects who participated in an alcohol-free campaign called Dry January, blood sugar levels were reduced by 23%, liver fat by 15% - 20%, and blood cholesterol by 5% compared to subjects who continued to drink as usual during a 2018 study in London [163].

The relationship between alcohol consumption, blood pressure, and high blood pressure is causal and reversible. Several studies of various types have reported a reduction in systolic blood pressure and diastolic blood pressure with significant clinical effects after a decrease in alcohol consumption [65]. A meta-analysis of 15 trial interventions involving a total of 2234 participants showed a 3.31 mmHg decrease in systolic blood pressure and a 2.04 mmHg decrease in diastolic blood pressure whenever alcohol consumption was reduced. The proportion of decreases in systolic blood pressure and diastolic blood pressure has a dose-response relationship with the reduction in alcohol consumption [164]. Another meta-analysis that included 36 clinical trials involving 2865 participants showed a dose-dependent decrease in blood pressure through the reduction of alcohol consumption. It was observed that systolic blood pressure fell by 5.50 mmHg and diastolic blood pressure by 3.97 mmHg in people who consumed at least 6 glasses of alcohol per day after the volume of alcohol consumed daily was halved [165].

Smoking cessation reduces mortality, the risk of developing cardiovascular disease, and the risk of retinopathy in smokers with type 1 and type 2 diabetes [166]. It significantly increases quality of life and life expectancy [167]. Smoking cessation increases insulin sensitivity and improves lipid profile [168]. A prospective study conducted in 2015 with 2,490 Japanese patients aged 20 years and older showed a linear and significant decrease in glycated hemoglobin (HbA1c) levels as the number of years of smoking cessation increased. A decrease in blood glucose was also observed during this study but not significantly [169]. Large U.S. cohort studies that followed patients for an average of 19.6 years had a higher risk of type 2 diabetes in people who were 6 years of withdrawal or less. On the other hand, 10 years after quitting, the risk of type 2 diabetes in these former smokers became equivalent to that of people who had never smoked [170].

Decreases in blood pressure were observed in a retrospective cohort study conducted among a population of people with hypertension in Taiwan region with high blood pressure followed from 2017 to 2018 in a smoking cessation program. The mean drop in systolic blood pressure was 5 mmHg and the mean drop in diastolic blood pressure was 3.1 mmHg [171]. In São Paulo, Brazil, a randomized controlled trial involving 113 smokers divided into two groups, the first of which consisted of 73 hypertensive people subjected to a 12-week smoking cessation and the second group of 41 hypertensive people not subjected to smoking cessation, also showed significant decreases in systolic blood pressure and diastolic blood pressure in the hypertensive group subjected to cessation.

The mean decrease in systolic blood pressure was 131 mmHg in the weaned hypertensive versus 125 mmHg in the unweaned hypertensive ($p = 0.004$). The mean decrease in diastolic blood pressure ($p = 0.031$) was 79 mmHg in weaned hypertensive patients compared to 77 mmHg in unweaned hypertensive patients [172].

Alcohol and tobacco consumption should remain low to promote a healthy lifestyle and improve health.

5. Limitations of the Study

By its very nature, this study may have limitations due to several factors. The study populations are heterogeneous, and the study protocols vary and do not necessarily follow the same methodology. With regard to the effect of micronutrient intake, the majority of the studies reviewed did not assess micronutrient deficiencies in the study populations. This undoubtedly has an impact on the effectiveness of the administered doses in controlling these conditions.

6. Conclusion

Diabetes mellitus and high blood pressure share several common risk factors. Their coexistence in the subjects increases the risk of complications, especially at the cerebral, ocular and renal levels. Diet, alcohol consumption, tobacco consumption and a sedentary lifestyle are major risk factors that can influence the occurrence or manifestation of other risk factors. In addition to macronutrients, micronutrients and phytonutrients play a key role in improving the overall nutritional status of people with diabetes mellitus and/or high blood pressure. A balanced diet and a healthy lifestyle would prevent or correct overweight, obesity and dyslipidemia. They would also mitigate the effect of factors related to genes, age and sex and reduce the risk of micro and macroangiopathic complications. The numerous research results are of great interest in developing and/or strengthening the nutritional and dietary management of these chronic diseases.

Author Contributions

Y.S.M.A.M. conducted the literature review, drafted the initial version of the article, and incorporated the revisions made by the co-authors. Z.N.A. selected the relevant documents for the draft and edited the initial version of the article. M.N.T.R. also made revisions to the initial version of the article. The final version of the article was reviewed and approved by all authors.

Conflicts of Interest

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

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